THE GLASS INDUSTRY

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PLANT IMPROVEMENTS COMPLETED AT CARR-LOWREY

New production unit replaces old facilities. Novel construction and location feature new factory and producer buildings. New equipment includes melting tank, complete with stack and gas producer, coal-handling system and gas mains.

The operator of the new tank at the Carr-Lowrey Glass Co., Baltimore, has at his elbow probably the best marine view of any tank man in the United States. The fine new factory building recently completed and occupied by this company stands on made ground extending out into the middle branch of the Patapsco River on the Westport side, the bulkhead line on the east end and about two-thirds of the north side of the building being only a few feet from the building walls. The stack and the producer house also stand on foundations in the river, each extending out from the main bulkhead around the building. All structure foundations are mounted on piles.

A view of the new plant addition from the river side is shown in Fig. 1. Several reasons dictated this somewhat unusual location of the new factory, the most important being the size of the available plot and the desire to secure a straight production line from the new tank to the shipping facilities in the older section of the plant. Furthermore, the use of the filled-in ground at the river edge permitted the new construction to proceed with least interruption to activities in other parts of the plant. At first glance it seems as if the new plant has been squeezed out into the river with little space to spare, but closer inspection brings out the fact that all structures and equipment have more than ordinary accessibility and that careful planning has resulted in very efficient use of the available space.

The new plant addition replaces the outmoded facilities of the company's old No. 4 tank and work on a new construction program was originally commenced about 1930. Activity was soon discontinued, however, after a small amount of foundation work had been done. In December, 1937, detailed plans were approved, contracts were let and the new unit was finally completed and placed in production in August of this year. The engineering of the entire project was handled by the Amsler-Morton Co., Pittsburgh, and was based on general specifications worked out by the Carr-Lowrey organization. Amsler-Morton also had the construction contract for the new tank, flues, stack, coal-handling system and gas producer.

New Factory Building

The new main building is of the usual structural and corrugated steel construction with glazed steel sash, and is about 89 ft. wide by 140 ft. long. The outside appearance of the structure is illustrated in Figs. 1 and 2,

Fig. 1. New Plant of the Carr-Lowrey Glass Co. on the Patapsco River in Baltimore. The melting tank is located in the end of the main building nearest the river and the new stack and producer house, with its coal-handling equipment, can also be seen.

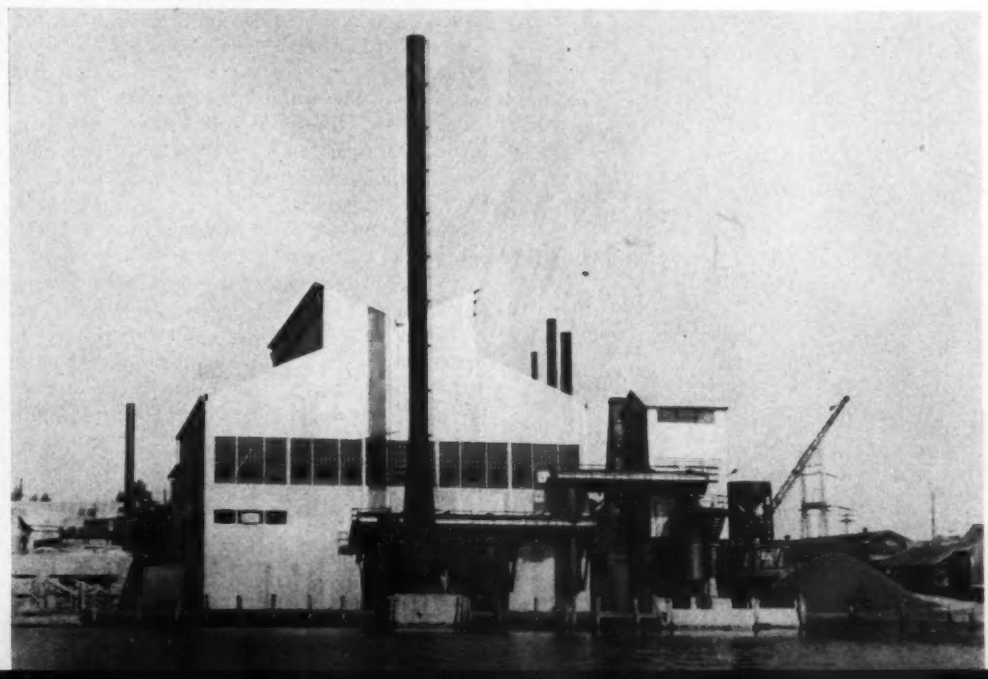
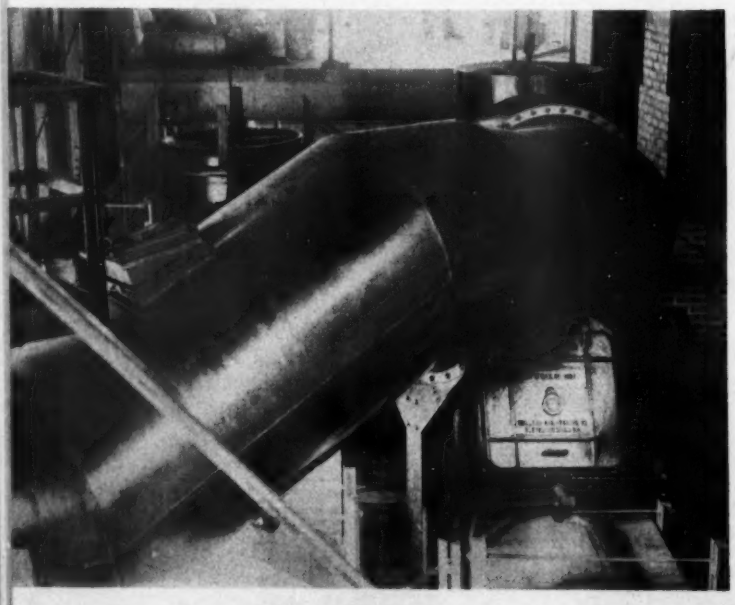


Fig. 2. View of the north side of the plant addition showing the coal-handling system and producer house. Crane and bucket for unloading coal barges appear at the extreme right.

notable features being the large window areas and the excellent arrangements for ventilation. As a matter of fact the entire building is strictly functional in design and particularly adapted for glass plant use. Openings for ventilation are provided at factory floor level by pivoted panels and at the top of the building monitor by louvres which swing outward at the top. Proper ventilation of spaces devoted to glass melting and forming is being recognized as an important factor in the design and construction of glass plant buildings, because of the enormous quantities of heat that must be dissipated. The new Carr-Lowrey building functions very well from the ventilation standpoint and indicates the possibilities from suitable utilization of proper space proportions, size and location of ventilation openings and simple, economical construction.

Fig. 3. Producer gas main with valves and furnace flues beneath the charging floor. Gas valve and flues at the lower right and air valve and flues behind and below the large gas main.



Although the Patapsco river at this point is an arm of Chesapeake Bay, unusual conditions of tide and wind sometimes produce flood conditions and this fact was considered in the building design. The basement floor is at a height which will be flooded only under extraordinary conditions and the flues are all located above this floor level. The main factory floor is 17½ ft. above the basement floor level. The charging floor occupies one 20-ft. bay of the building at the river and is 9 ft. above the factory floor. From the factory floor to the bottom of the roof trusses the distance is 32 ft. All floors are of reinforced slab construction. The construction of the building was handled by Herbert J. West, contractor, of Baltimore.

New Stack and Producer House

The new stack is of the self-supporting steel type, designed by Amsler-Morton and built by McNamara & Co., Baltimore. It has a diameter of 10½ ft. at the base and 4¼ ft. at the top, the height being 125 ft. The stack lining is composed of 4½-in. firebrick. As stated before, the stack stands on a separate pile foundation adjacent to the bulkhead at the river end of the building, the distance from the building to the center line of the stack being 25 ft. The producer house is also built of structural and corrugated steel, its location relative to the main building being shown in Figs. 1 and 2. The house is approximately 18 ft. square and is separated from the north side of the main building by a distance of about 17½ feet.

Coal is delivered to the Carr-Lowrey plant in barges and little difficulty is experienced at any season. A neighboring public utility plant also receives its fuel by water, so navigation is maintained even when the river is occasionally frozen over. The coal barge is moored alongside the bulkhead north of the new building and beneath a truss framework which supports a hopper and one end of the coal-handling conveyor. The barges are unloaded by a grab-bucket and derrick, which can be

seen at the right in Fig. 2, the bucket delivering either to the hopper at the coal conveyor or to a pile on the ground near the derrick. The capacity of the bucket is 1,250 lb. and the conveyor hopper holds 15 tons.

The coal conveyor is fitted with a Goodyear rubber-faced belt and delivers the coal to a 30-ton hopper located immediately above the producer. The 10-ft. producer was furnished by the Wellman Engineering Co. and is of the rotating-shell type with bell-type feeder. Ash removal is automatic and the producer is located at such a height that the ashes fall by gravity into buggies which are hauled away by a small tractor. From the producer house the gas main passes along outside the east wall of the main building and can be seen in Fig. 1. The gas main was built by Charles T. Brandt, Inc., Baltimore, and has an outside diameter of 5½ ft. outside the building. It is lined with 2½ inches of Johns-Manville Super-X insulation and 4½-in. firebrick. Three dust legs are provided, as shown in the illustration, together with a burnout connection to the horizontal flue leading to the stack.

As it passes into the building the main leading to the new tank is reduced to 52 in. outside diameter and it is further necked down to 45 in. before it enters the valve. This section of the main is shown in Fig. 3, together with the valves and flues beneath the charging floor. Outside the building the main is supported on suitable brackets attached to the building columns, structural-steel supports being provided for the inside section. A 24-in. Wellman gas-reversing valve is located on top of the gas flue and immediately behind the columns supporting the melting end of the furnace. The air inlet and reversing valves are located above the brick air flue, this flue being connected to the stack by a horizontal section of steel.

Details of Melting Tank

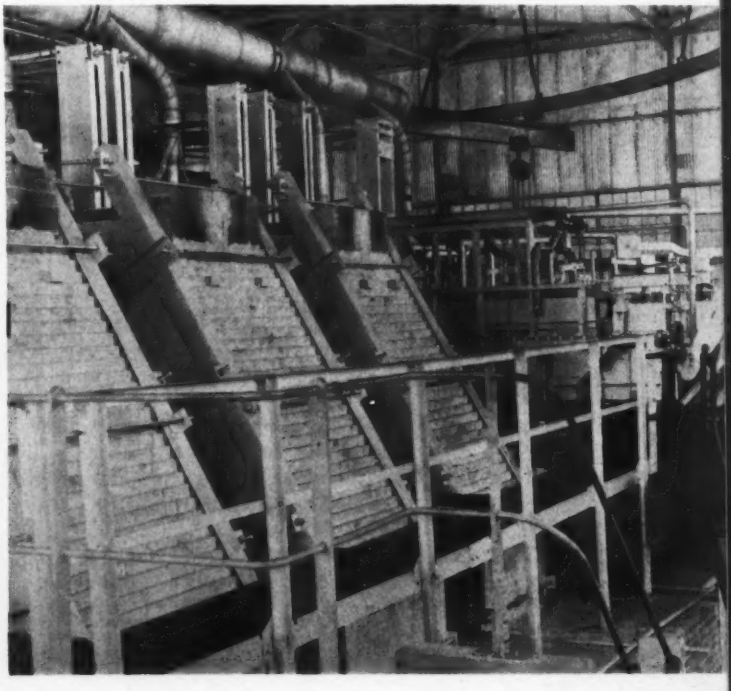
The new tank has a melting end 16 ft. wide and 22 ft. long, separated from the refining end by a bridge wall of somewhat unusual construction, as shown in Fig. 4. This bridge wall has two throats, each 6 in. high by 27 in. long, and is topped by a shade wall of 12-in. silica brick. The nose of the tank has a radius of 9 ft., the center being 4 ft. in front of the bridge wall. There are seven feeder openings in the front of the tank, each being furnished with a Corhart bushing of special shape so that the feeder will extend in the proper direction. The melting end has three ports on each side with sloping passages above the checkers, as shown in Fig. 5. The ports have different widths, the one nearest the filling end being 41 in. wide, the second 36½ in., and the third 32 inches.

The tank is charged through two doghouses at the rear and the depth of metal in the melting end is 32 in. In front of the bridge wall the bottom of the tank is stepped up to provide a depth of 18 in. in the refining end. Findlay 12-in. flux blocks are used in the bottom of the melting end and all side walls, including doghouses, are 12-in. Corhart. The bottom of the refining end is somewhat unusual, with 12-in. Corhart blocks laid over 6-in. Findlay clay bricks. Silica tuckstones and crown brick were furnished by Harbison-Walker, as were also the straight jack arches over the ports.

Pressure in the furnace is automatically controlled by an Askania regulator which operates a butterfly damper located in the steel flue leading to the stack. A Leeds & Northrup instrument of the split-range type records temperatures at four points, platinum-rhodium couples being located in the crowns of the melting and refining ends and base-metal couples in each of the air flues.

Fig. 4. Bridge wall and double throat of the new Amsler-Morton tank at Carr-Lowrey. Note the shade wall mounted on top of the bridge wall.

Fig. 5. Side view of the new Carr-Lowrey tank showing the sloping port passages and feeders. The radial hoist handles feeder and machine parts.



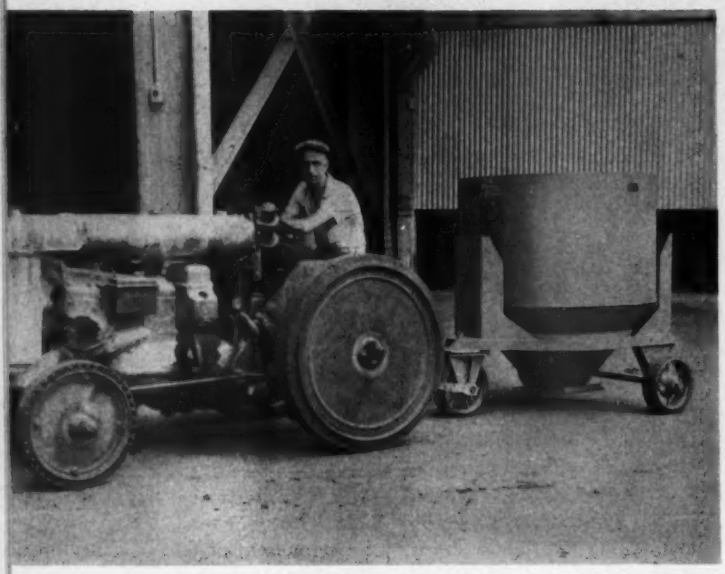


Fig. 6. Loaded batch buckets are carried from the batch house to the new building on three-wheeled buggies drawn by a gasoline tractor.

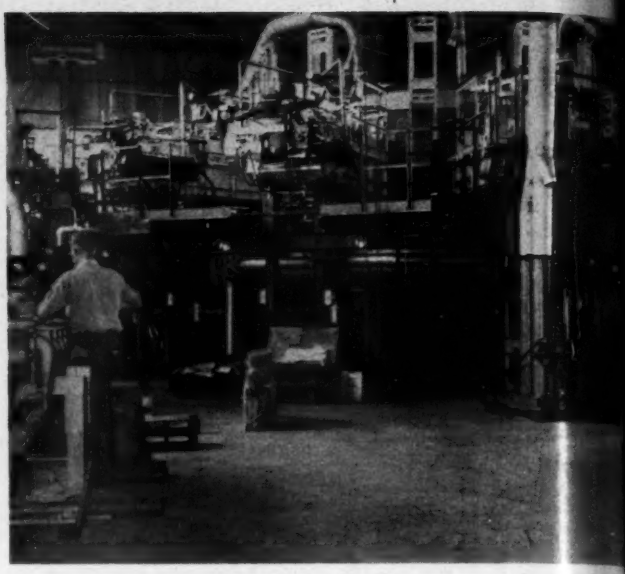


Fig. 7. View toward the front of the tank showing Hartford-Empire feeders and some of the forming machines in operating position.

The recorder and the Askania regulator are located on the charging floor at the rear of the tank. Piping for block cooling was furnished by C. T. Brandt, Inc., and the air is supplied by two motor-driven fans.

Batch Containers and Handling Equipment

The new tank has a capacity of about 45 tons of soda-lime bottle glass per day and the batch is mixed in the old batch house, which is located a considerable distance from the new building. At the mixer house the batch is loaded into buckets, each of which has a capacity of 3,500 lb. These buckets are 48 in. in diameter and about 51 in. high, with a sliding gate in the bottom and a heavy lifting bail near the top. The filled buckets are placed in special three-wheeled buggies which are then towed into the basement of the new building along the concrete roadway shown in Fig. 2. Fig. 6 shows the gasoline tractor with one of the batch buckets on its buggy.

Loaded batch buckets may be stored either in the basement or on the charging floor, short steel-plate cylinders being provided at these points to receive the conical bottoms of the buckets and hold them upright on the floor. From the basement to the tank feeders the batch buckets are handled by a mono-rail hoist supported by a structural framework between the roof trusses above the charging floor. The mono-rail makes a loop behind the furnace, as shown in Fig. 7, and both sides of the loop switch into a straight section which runs along the north wall for a short distance. This straight section is immediately above a 6-ft. by 6-ft. opening in the factory floor, just beyond the edge of the charging floor. Furnished and installed by the Lansdale Foundry & Machine Co., the mono-rail supports a three-phase trolley carrying 25-cycle current at 220 volts.

The Shepard-Niles electric hoist which operates on the mono-rail has a capacity of 3 tons and a lift of 48 ft. Its push-button control is attached to the hoist by a long cable and is carried about by the operator as the hoist is moved from place to place. The lifting speed of the hoist is 29 ft. per minute and the traveling speed 150 ft. The bottom of the mono-rail is 18 ft. above the charging floor and slightly over 44 ft. above the floor of the basement. With the hoist positioned above the opening in the factory floor, the loaded batch bucket can be raised from the basement and switched to the front section of the loop to be deposited on the tank feeder, as shown in Fig. 7. If not needed immediately, however, the batch container can be switched to the other section of the loop and stored along the end wall of the building on one of the cylindrical holders previously mentioned.

Feeders and Forming Machines

The tank charging apparatus is a new dual type furnished by the Simpson Foundry & Machine Co., and incorporates two H-E feeders in a single framework. Each feeder serves one doghouse.

The forehearths of five of the Hartford-Empire feeders are 12-ft. long, the other two having a length of 14 ft. The tank is equipped with a Hartford-Empire glass level indicator and Leeds & Northrup instruments indicate temperatures at two points in each forehearth. Most of the forming machines were transferred from the old tank, two new Hartford I-S machines also being installed. Fig. 8 is a view of the front of the tank with the feeders and some of the machines in working position. It will be noted from this picture and from Fig. 5 that stairs and platforms give easy access to all parts of the tank and feeders. Fig. 5 also shows another useful and ingenious piece of apparatus in the form of an I-beam pivoted at one end above the nose of the tank, the outer end swinging around on a trolley that runs on a semi-circular track supported from the roof trusses. A trolley runs in and out on the I-beam and supports a

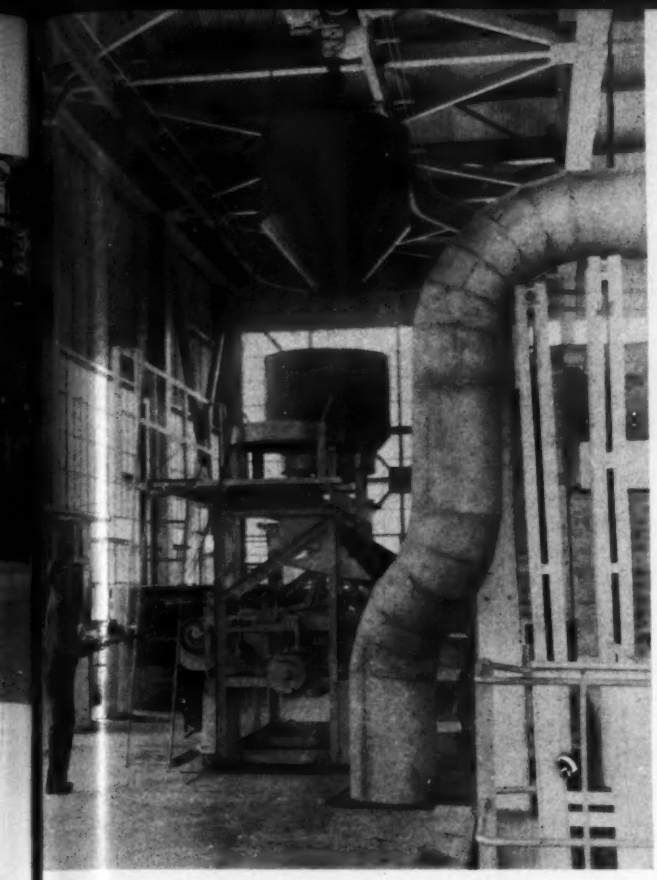


Fig. 8. Batch buckets are lifted from the basement and placed on the tank charger by an electric mono-rail hoist. Operator controls hoist through the push-button box in his hands. The charger is a new dual type which serves two doghouses.

hoist by means of which parts of any of the feeders and machines can be lifted and handled quickly and conveniently. Separate fans provide air for machine and man cooling, respectively.

The annealing equipment includes six Hartford-Empire lehrs, all of which have an over-all length of 75 ft., including a 60-ft. tunnel and a 15-ft. open discharge end. Types and sizes are as follows: three type E, 36 in. wide; one type E, 42 in. wide; and two type LT, 42 in. wide. Four of the lehrs are equipped with H-E stackers and small ware from two of the machines is delivered to one lehr by belt. The line of containers manufactured by Carr-Lowrey includes pharmaceutical, perfume and proprietary bottles.

Bottles are inspected and packed at the ends of the lehrs and the packaged ware is transported to the warehouse on a live-roll conveyor. The new building adjoins an older building at its westerly end, both floors being on the same level. In the last two 20-ft. bays of the new building a mezzanine is located 14 ft. above the factory floor and this space is used for the storage and fabrication of cartons. A traveling hoist is arranged to lift carton material from a truck platform outside the building to the mezzanine and transfer it inside the building. For protection against the weather a truck-unloading canopy and an enclosed well are provided. The fabricated cartons are delivered to the packing stations at the ends of the lehrs by means of roller chutes.

The successful conclusion of this major improvement program at the Carr-Lowrey plant reflects great credit on all those who participated in the development, especially Executive Chairman, Carl G. Hilgenberg, and President George F. Lang, whose energy and foresight made the betterment possible, and General Plant Superintendent Charles B. Garwood, who was in immediate charge of the project. Philip W. Robinson was resident engineer for the Amsler-Morton Co. A feature of the new production unit is its well-coördinated design, in which all factors of suitable buildings, together with proper selection and location of equipment, have been combined. The appearance and accessibility of the various buildings and apparatus are outstanding in this new factory and should provide a plant that is relatively easy to maintain as well as efficient in operation.

INTERNATIONAL CONGRESS ON GLASS

Plans for the International Congress on Glass to be held in Berlin and Munich, Germany, July 6-15th, 1939, are gradually taking shape. The aim of the Congress is the general advancement of the technic, science, art and culture of glass and the exchange of new discoveries and experiences. Lectures and reports will be given by both foreign and German experts, and visits to various plants are planned.

The Congress will open in Berlin on Thursday, July 6th, and remain there until the 7th. The sessions here will be mostly social and devoted to visiting various industrial and hand-made glass plants. The journey to Munich will be broken by a one day's stopover in Dresden to witness the opening of an exhibition, "Saxonian Glass New and Old." The technical sessions, divided into groups, will begin in Munich on Tuesday, July 7 and continue through the 14th.

The management of the Congress is in the hands of a committee consisting of: President, Dr. O. Seeling, Furth, Bavaria; Treasurer, Dr. K. Mey, Berlin; General Manager, Dr. Ing H. Maurach, Frankfurt/Main. In addition, there will be representatives in the various other countries, forming an International Glass Commission under the presidency of Professor W. E. S. Turner, Society of Glass Technology, Sheffield, England.

All interested in attending the International Congress on Glass and obtaining advance information on papers, specific plans, etc., should communicate with Dr. K. W. Schulze, International Kongress Fur Glass, Geschaftstelle Frankfurt/Main, Junghoffstrasse 27, Germany.

OPTICAL SOCIETY MEETS OCT. 27-29

The 23rd annual meeting of the Optical Society of America will be held Oct. 27-29, 1938, at the General Brock Hotel, Niagara Falls, Canada. In addition to the usual program of papers contributed by members, the meeting will include: 1. a symposium on the optics of illumination; 2. a popular lecture by Robert McMath, director of the McMath-Hulbert Observatory of the University of Michigan, illustrated with astronomical motion pictures, including spectroheliographs of remarkable solar prominences, and 3. visits to the University of Buffalo, the Spencer Lens Co., the Cyanamid Plant, the Queenstown Power House, the Whirlpool, etc.

The meeting will be open to non-members as well as members of the Society. Non-members desiring information and advance programs should communicate with L. B. Tuckerman, secretary, Optical Society of America, National Bureau of Standards, Washington, D. C.

The new Libbey-Owens-Ford technical building on East Broadway in Toledo. The nearer end of the building is occupied by the engineering staff, space for the research and laboratory work being provided in the portion beyond the entrance.

NEW L-O-F TECHNICAL BUILDING COMPLETED

Located far back from the street, the new technical building of the Libbey-Owens-Ford Glass Co. on East Broadway in Toledo faces a wide expanse of well-landscaped lawn and rather seems to fit right into the setting and add a colorful accent to an outlook that is quite unusual in the workaday atmosphere of an industrial plant.

The colorful appearance of the building is achieved by bands of Vitrolite glass which extend all along the facade. Between the windows tan Vitrolite is used, with narrow red bands of the same material above and below the windows. A wide concrete drive curves up from the street to the entrance. Here again, Vitrolite, in red, tan and black, is used for ornamentation and a modernistic touch is given by a metal coping and metal casings for the doors and transom. Near the top of the building metallic letters spell out the initials of the company and the insignia that has become familiar on Libbey-Owens-Ford products appears just above the door.

The floor of most of the south wing is at ground level so that heavy machinery can be operated without producing detrimental vibrations. A basement floor is provided only under a portion of this wing and the south end of the building and furnishes space for a dark room, record vaults and testing rooms. A considerable portion of the basement area has forehandedly been left unassigned for future requirements.

The equipment of the laboratories and testing rooms is very complete and up-to-date in every respect. In the main building are facilities for organic research, together with analytical and physical laboratories and a calorimeter room. The ground-floor section of the wing houses a great variety of equipment, including machine shop, furnace and mixing, cutting and grinding, adhesives, high-temperature experiments, plastics, presses and autoclaves. In the basement are located rooms for drop test, refrigerating machine, plastic research, spectograph, ultra-violet and cold tests.

Passing along the corridor toward the north end of the main building, the glass-enclosed offices for the engineering staff are at the left along the front wall. On the right is an office reserved for the use of D. H. Goodwillie, Executive Vice-president, together with a library and conference room.

The new L-O-F technical building is the outcome of several years of planning and design and provides a maximum of facilities for all of the general engineering and research work with a minimum of space.

View in the entrance lobby looking down the corridor into the research end of the building. A modern note is struck by the metal trim, furniture and clock. The walls are of tan Vitrolite with horizontal black stripes.

View in the chemical research and testing laboratories. Hoods are located along the wall at the left.

The engineering department drafting-room in the north wing. In the middle distance Chief Engineer Drake and members of his staff tackle a tough problem. Glazed brick walls are largely used throughout the building.

GLASS DIVISION HOLDS SUCCESSFUL MEETING

Almost an even hundred were aboard the *President Warfield* when the Old Bay Line steamer pulled away from the wharf at Baltimore on Friday evening, September 9th, conveying members of the Glass Division to their tenth annual meeting. The delightful sail down the Chesapeake proved a perfect prelude to the meeting proper. An excellent dinner, a few conferences notable for their brevity, bridge for the addicts, innumerable reunions of old friends—and an evening of good fellowship passed all too quickly.

Rounding Cove Point, three long blasts of the whistle brought everyone on deck to watch the long finger of the ship's searchlight seek and finally rest on Dr. Flint's cottage, where ten years ago a handful of glassmen met for what was destined to be the first Fall meeting of the Glass Division.

Bright and early (not too bright, but very early) Saturday morning, the pilgrims landed and were given a few hours in which to prepare themselves for the first technical session. There were two of these meetings, held each morning. More will be said of these presently; but for the moment we will turn to the features of an entertainment program that was extremely noteworthy.

The first afternoon was spent at Williamsburg. Two large buses, filled to capacity, traveled over a 40-mile stretch that is one of the richest historically in the whole United States. Then Colonial Williamsburg, rebuilt and restored as an exact replica of the days when it was the seat of authority and the social center of the Colonial government. For three hours, the party hurried from building to building, from room to room, recapturing from competent guides the life and atmosphere of two and a quarter centuries ago. Considerately, the convention committee had arranged for a full harvest moon to light the trip homeward.

Saturday evening was a banquet, more or less formal, presided over by Chairman Roche. Speakers included Drs. Purdy, Littleton, Scholes, Preston and Flint. Preston gently chided the Institute of Ceramic Engineers for its membership questionnaire, and also spoke of the superiority which all glassmen should rightly feel over their chosen profession. Flint disclosed some inside information concerning the celebrated Cove Point meeting. Littleton took the historical baton from the hands of Francis Flint and carried the story on through the days at Lake Keuka. Purdy was a model of brevity. Scholes earned laurels as toastmaster and raconteur. Festivities were brought to a close by a dance on the Marine Roof.

Thanks to arrangements made by ex-Chairman A. N. Finn, an opportunity was afforded the party to visit Sunday morning the cruiser *Honolulu*, as she lay off Norfolk.

Sunday afternoon, many went fishing, others played golf, while the majority took another sight-seeing trip, this time to Jamestown, site of the first glass furnaces in America.

After crowding so much into so little time, it was a rather breathless and subdued party which climbed the gangplank Sunday night for the homeward journey. But there was no doubt as to the general feeling that the meeting had been a huge success. For this, thanks are due to Vice-chairman Lester, in charge of arrangements.

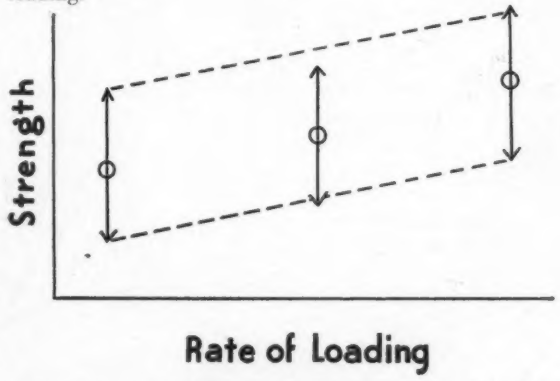
The Technical Sessions

The morning session on Saturday was devoted to a symposium on the strength of glass. Researches, under the general direction of Dr. J. T. Littleton, Chairman of the Sub-Committee on Mechanical Strength, of the Committee C-14 of the A.S.T.M., were reported from several laboratories.

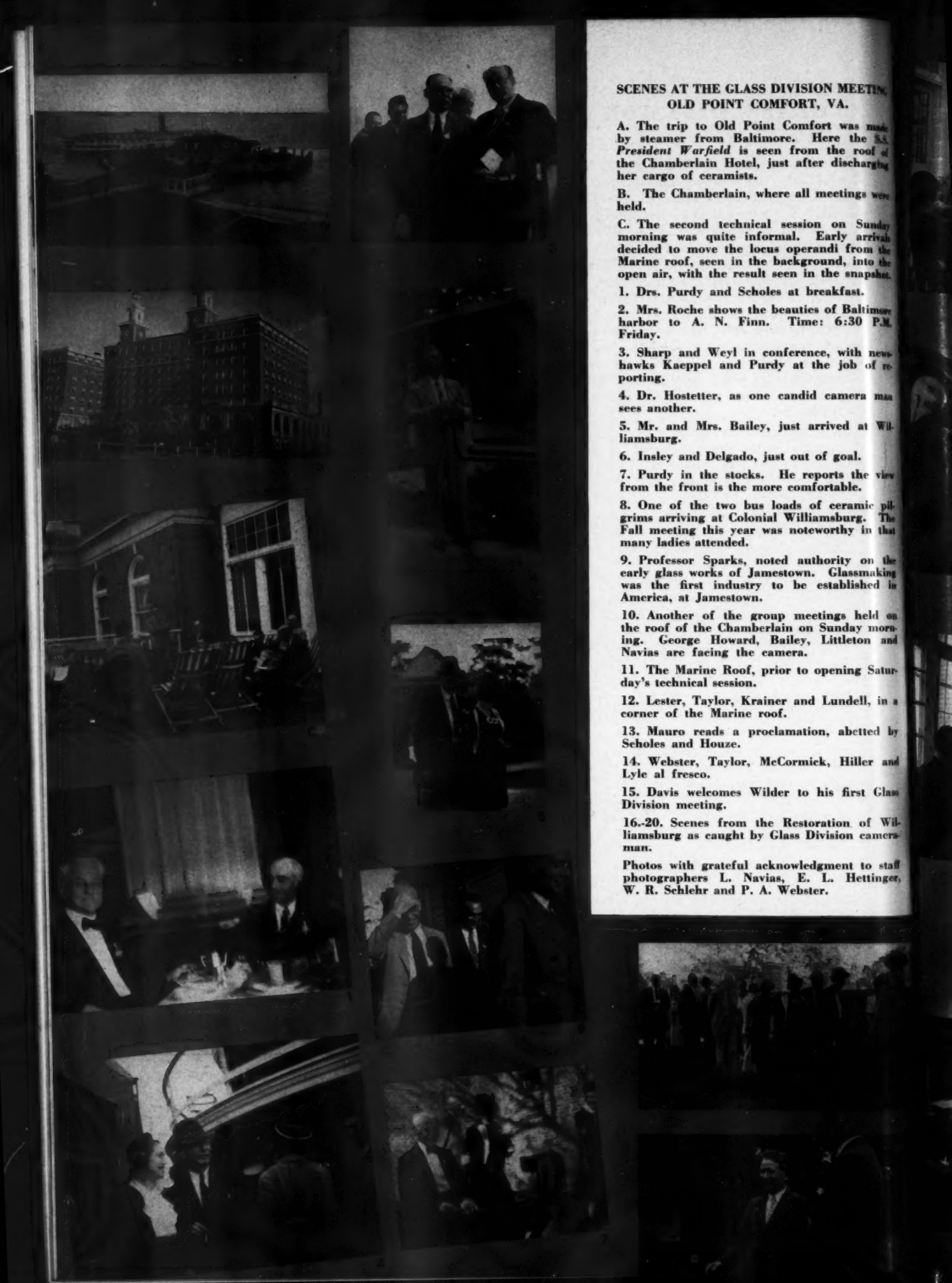
In these latest experiments on the measurement of tensile strength, attention was paid to criteria and conditions established by James Bailey. It was assumed that all specimens had been given commercial annealing. The specimens in the form of rods were in diameters of 5, 8 and 11 millimeters. Length of support between knife edges, and especially the rate of application of the load, were specified conditions.

While a large body of numerical data was presented, the figures are not yet released for publication; and in fact, much work remains to be done in the sorting and correlation of these data before they enter the literature. As in previous work of this kind, and in fact, as experimenters have learned confidently to expect, there is a considerable spread, often as much as 50 per cent, between values obtained for any one set of conditions. The point was brought out in the discussion, that many more individual specimens must be broken than the number reported (usually about 15), before it becomes justifiable to select a mean value for each diameter and rate of loading.

Nevertheless, the accumulated evidence begins to show that it is now possible to get at least an area within which breakage may be expected to occur; or in other words within which the calculated tensile strength lies. This area is indicated in the following figure, which is not drawn to scale, and which is intended to show merely the trend rather than specific values. In this figure the double-ended vertical arrows indicate the spread of strength values for a given diameter and type of specimen for a certain rate of loading. The circle in an arrow represents a mean value. The slope of the line joining these circles or mean points for several rates of loading indicates the increase in apparent strength with increased rate of loading.



From the scientific point of view, reports such as these indicate the definite progress that is being made and the change in mental attitude of investigators toward this baffling matter of tensile strength. Some years ago,



SCENES AT THE GLASS DIVISION MEETING, OLD POINT COMFORT, VA.

A. The trip to Old Point Comfort was made by steamer from Baltimore. Here the S.S. *President Warfield* is seen from the roof of the Chamberlain Hotel, just after discharging her cargo of ceramists.

B. The Chamberlain, where all meetings were held.

C. The second technical session on Sunday morning was quite informal. Early arrivals decided to move the locus operandi from the Marine roof, seen in the background, into the open air, with the result seen in the snapshot.

1. Drs. Purdy and Scholes at breakfast.

2. Mrs. Roche shows the beauties of Baltimore harbor to A. N. Finn. Time: 6:30 P.M. Friday.

3. Sharp and Weyl in conference, with newshawks Kaeppel and Purdy at the job of reporting.

4. Dr. Hostetter, as one candid camera man sees another.

5. Mr. and Mrs. Bailey, just arrived at Williamsburg.

6. Insley and Delgado, just out of goal.

7. Purdy in the stocks. He reports the view from the front is the more comfortable.

8. One of the two bus loads of ceramic pilgrims arriving at Colonial Williamsburg. The Fall meeting this year was noteworthy in that many ladies attended.

9. Professor Sparks, noted authority on the early glass works of Jamestown. Glassmaking was the first industry to be established in America, at Jamestown.

10. Another of the group meetings held on the roof of the Chamberlain on Sunday morning. George Howard, Bailey, Littleton and Navias are facing the camera.

11. The Marine Roof, prior to opening Saturday's technical session.

12. Lester, Taylor, Krainer and Lundell, in a corner of the Marine roof.

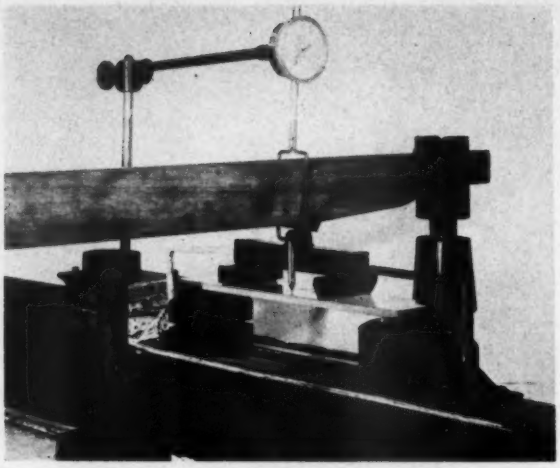
13. Mauro reads a proclamation, abetted by Scholes and Houze.

14. Webster, Taylor, McCormick, Hiller and Lyle al fresco.

15. Davis welcomes Wilder to his first Glass Division meeting.

16.-20. Scenes from the Restoration of Williamsburg as caught by Glass Division cameraman.

Photos with grateful acknowledgment to staff photographers L. Navias, E. L. Hettinger, W. R. Schlehr and P. A. Webster.



Bailey's breaking strength apparatus, as modified by Gregorius.

the opinion apparently prevailed that the tensile strength of glass had a definite value, depending perhaps on the composition of the glass, and somewhat independent of many of the conditions that are now thoroughly recognized. The fact that now emerges with increasing clarity is, that the tensile strength of glass cannot be given an assigned value; that it is closely bound up with the character and size of the specimen, with the rate of loading, and with the condition of the surface of the specimen. All this is manifestly disappointing, when we are looking for some exact number to attach to this engineering material; but it is encouraging, because it represents the truth and not optimistic fiction. Another important point that comes to light is, that there is no justification for studying the effect of composition on tensile strength, until more is learned about means of arriving at approximate values for any particular kind of glass.

The several researchers are to be complimented upon carrying out this tedious work with so much care and attention to detail. The reasonable criticism: that even these numerous tests do not by any means include enough individual breakings, means that still more painstaking work must be done, and much must be learned about whether to discard certain unreasonably high and unreasonably low values, before the "area" described above can be reduced to even a narrow band, not to say anything approaching a line.

Thermal shock tests, which are in reality tensile strength tests in which the tensile stress is produced by sudden cooling of the surface (water quenching), were also shown to be subject to the same kind of variation. It was brought out that the thermal endurance of glass, as glass, is a fiction. We can speak only of the thermal endurance of particular specimens of different glasses whose shape, size, heat treatment and surface condition all have important bearings on the result. However, since the tensile stress developed on quenching depends directly upon the coefficient of expansion of the glass being tested, we have here at least one rather definite physical property of the glass affecting its thermal endurance; and it is still reasonable to say that the degree of thermal shock to be endured by specimens of different composition, but otherwise identical, will be inversely as the respective coefficients of expansion of the glasses.

Among the speakers on these subjects were Littleton, Bailey, Burch, Speh, Gregorius, Howard, Finn, Flint and Scholes; while several other members discussed the papers from the floor. Doctor Preston discussed and demonstrated experimentally ways in which bottles may be mistreated to the detriment of their mechanical strength.

Doctor Sparks, of Jamestown, inviting the members to visit that historic town, pointed out that the first glass in America was made there by John Smith, in 1608. Ruins, discovered a few years ago, are undoubtedly those of a furnace built in 1622 by one George Sanders. Another furnace a mile away dates from 1666. These remarks reminded the technologists once more that ours is the oldest manufacturing industry in the United States.

Groups assembled on the hotel roof on Sunday morning for less formal discussions. One of these, led by Doctor Lundell, examined in detail the analytical results reported by several of the coöperating laboratories on the sample of container glass recently circulated by the National Bureau of Standards. About ten years ago, a similar sample was analyzed, and it is interesting to note that the present results are much more closely in agreement, indicating either that our methods are now improved, or else that the technique of glass analysts is definitely better, perhaps both. The worst results still appear in the values for silica, while the values for component oxides occurring in small amounts are in very good agreement. Values for the alkalies by different methods agree fairly well. One of the points brought out in the discussion was, that apparently we must be content with values for silica within about 0.25 per cent, certainly not better than 0.1 per cent agreement. In this work, stress was laid on the comparison of different methods which might be designated routine and umpire methods, rather than upon any effort to determine the precise composition of the glass where all the analysts were using specified methods for the different oxides.

At the same time, the tensile strength investigators, under Doctor Littleton, discussed their problems, and arranged for further study. This subject remains one of coöperation between our Division and the Society of Glass Technology of England, and investigators on the Continent.

Although the Third International Congress of Glass, scheduled for meeting in Germany next July, must have been in the back of the minds of many of the members, no mention was made of the Congress during the formal sessions. This is not surprising, in view of the disturbing character of current newspaper headlines.

The usual personal conferences in groups of twos and threes, which are such valuable features of these summer meetings, were going on at all times. These, in addition to the more formal papers and discussions, made this meeting one of the best thus far enjoyed by the Glass Division. The "steering committee" of the Division, consisting of those concerned with arranging its programs and enlarging its membership, assembled and devoted considerable time and discussion to the character of the program to be presented at the Chicago Meeting of the Society, in April, 1939. Definite plans are afoot to include in this program more papers of direct interest to the production men, as well as papers of a more scientific character for the technologist.

THE TERNARY AND QUATERNARY SYSTEMS ALKALI OXIDE—CaO-SiO_2-CO_2*: II

By CARL KRÖGER

Institute for Chemical Technology, University of Breslau

This is the second instalment of Dr. Kroger's interesting discussion. The first instalment, which appeared on page 341 of the September GLASS INDUSTRY, *covered the following systems: Li_2O-CaO-CO_2, K_2O-CaO-CO_2, Na_2O-CaO-CO_2, Na_2O-K_2O-CaO-CO_2, Li_2O-SiO_2-CO_2.—The Editor.*

6. The System K_2O—SiO_2—CO_2

(*a*) *K_2O—SiO_2.* Fig. 3 shows the equilibrium diagram up to the decomposition point of metasilicate as investigated by Kracek, Bowen and Morey. There occur three congruent melting compounds—$K_2Si_4O_9$, $K_2Si_2O_5$ and K_2SiO_3. The equilibrium between quartz and tetrasilicate is established very sluggishly. $K_2Si_4O_9$ does not crystallize as such from the dry melts, so that to a certain extent the field of instable crystallization of tridymite and disilicate could be plotted. Thus, a supercooled melt of the composition $K_2Si_4O_9$ at 520° showed a primary crystallized tridymite along with glass. The stable eutectic between $K_2Si_4O_9$ and $K_2Si_2O_5$ lies at 752° and 69 per cent SiO_2; that between $K_2Si_4O_9$ and quartz at 764° and 72 per cent SiO_2. At 775° and 45.5 per cent SiO_2 there is the eutectic between di- and meta-silicate. At higher pressures the $K_2Si_4O_9$ melts incongruently, and at still higher pressures (1250 megabars) only reactions between quartz and disilicate take place below 640° in the solid state. A stable eutectic between quartz and disilicate results.

The volatilization of the melt at higher temperatures is dependent on the surface and the concentration of the volatile constituent.

K_2SiO_3. Melting point 976°. Forms rhombic crystals with positive double refraction. Index of refraction $\gamma = 1.528$; $\alpha = 1.520$.

$K_2Si_2O_5$. Melting point 1035°. Conversion point 590°. The modification stable at higher temperatures is capable of taking up small quantities of K_2O and SiO_2 with the formation of mixed crystals. The mixed crystals decompose on cooling to 814° and 933° respectively. Sp. gr. $d\,\frac{4}{25} = 2.456$. $K_2Si_2O_5$ forms rhombic plates, optically negative, strongly double refractive. Index of refraction $\alpha = 1.503$, $\gamma = 1.513$. The viscosity of the disilicate melt decreases continuously from 9000 cgs (poise) at 1000° to 80 cgs at 1400°.

$K_2Si_4O_9$. Melting point 765°. The pressure relationship of melting point for 1 to 1000 megabars is given by the formula $dt/dp = -60°$. The congruent melts of the compound go into an incongruent one with the separation of a quartz on raising the pressure above 140 megabars. Conversion point 592°. The volume effect on inversion amounts to 0.0031 cm^3/g. The coefficient of the effect of pressure on the inversion point is

$$\frac{+28°}{1000} \text{ megabars.}$$

Sp. gr. $d_{20} = 2.335$. $K_2Si_4O_9$ forms plates of optically positive character with large double refraction. Index of refraction $\alpha = 1.477$, $\gamma = 1.482$.

(*b*) *K_2O—SiO_2—CO_2.* $K_2Si_4O_9$ no longer reacts with CO_2; hence, equilibria with a higher SiO_2 silicate do not occur. The first equilibrium established at low temperatures is between tetra-and di-silicate. In every case, as in the Na_2O system, it is possible for melts richer in SiO_2 to take up CO_2 with the formation of carbonate, so that in these melts SiO_2 molecules can exist alongside carbonate molecules.

THE STABLE EQUILIBRIA

1. $[K_2Si_4O_9] + [K_2CO_3] \rightleftarrows 2\,[K_2Si_2O_5] + (CO_2)$

With the interaction of carbonate on tetrasilicate, a bivariant equilibrium occurs, caused by the formation of a solid solution of disilicate in carbonate. With a content of 0.21 disilicate, saturation is reached at 460°; at lower temperatures, still lower disilicate contents cause

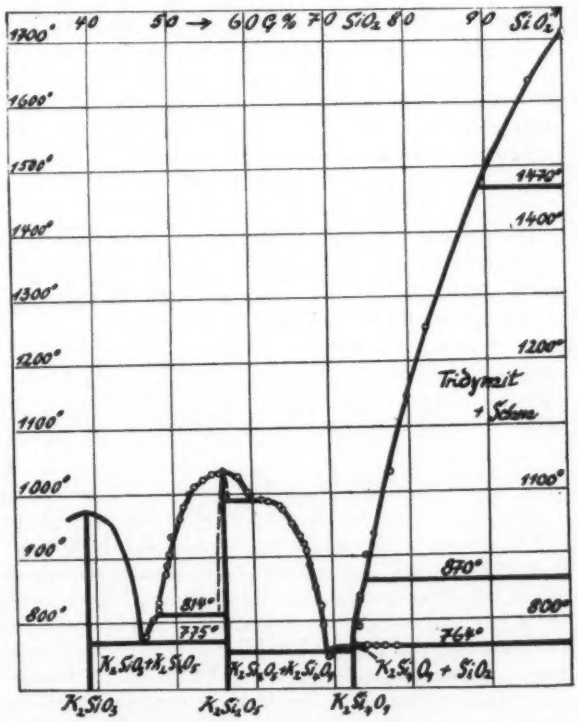


Fig. 3. Decomposition of metasilicate (Kracek, Bowen and Morey).

*Abstracted by Robert F. Ferguson from *Glastechnische Berichte 15*, 335-346, 371-379, 403-416 (1937), and published with the kind permission of the author and the publishers.

saturation. The initial reaction pressures of these bivariant parts are:

t (°C)	330	360	377	437
p (mm)	125	190	268	440

With increasing carbonate conversion, the pressure then decreases at 460° as follows:

Conversion (%)	10	16.7	19.7	21.6
p (mm)	465	286	205	205

The reaction is reversible. If saturation of the carbonate by disilicate exists, then the pressure of the above monovariant equilibrium is:

t (°C)	380	396	455	460	484	487	495	500
p (mm)	43	55	250	239	505	583	615	805

These pressures also are reversible.

The establishment of pressure can take place in a long or short period of time. In the presence of traces of catalytic water vapor the equilibrium can be established in 20 to 40 hours; otherwise, it takes about 10 times as long. The absorption of CO_2 by water-free $K_2Si_4O_9$—$K_2Si_2O_5$ mixture requires the same time at temperatures below 400°. At higher temperatures the absorption takes place more quickly, and at 486° equilibrium is reached in about 100 hours. The catalytic acceleration of traces of water vapor is shown by the following equations:

$$K_2Si_4O_9 + H_2O \rightleftarrows 2KHSi_2O_5$$
$$2KHSi_2O_5 + K_2CO_3 \rightleftarrows 2K_2Si_2O_5 + CO_2 + H_2O$$
$$K_2Si_4O_9 + K_2CO_3 \rightleftarrows 2K_2Si_2O_5 + CO_2$$

Influence of water vapor on the equilibrium: $K_2Si_4O_9$ and also $K_2Si_2O_5$ are strongly hygroscopic. On prolonged grinding with K_2CO_3 they draw moisture from the air, which on heating cannot be driven off absolutely, but tends to form the compound $K_2Si_4O_9 \cdot H_2O$, which is considered as a potassium hydrosilicate. Under high vapor concentration $K_2Si_2O_5$ can form a hydrate with 1 mol H_2O decomposable at 400°, while $KHSi_2O_5$ melts congruently at 510°. Hence, if $K_2Si_4O_9$-K_2CO_3 mixtures which have absorbed considerable water are heated in a vacuum apparatus, then after pumping out the first water vapor, the following non-reproducible CO_2 pressures are observed:

t (°C)	230	409	390	305
p (mm)	103	689	576	155

The pressures indicate a bivariant equilibrium:

$$2[KHSi_2O_5] + [K_2CO_3] = 2[K_2Si_2O_5] + (CO_2) + (H_2O)$$

From then on, one observes exclusively the pressures of the normal $K_2Si_4O_9$—$K_2Si_2O_5$ equilibrium.

$$2.\ K_2Si_2O_5 + K_2CO_3 \rightleftarrows 2\ K_2SiO_3 + (CO_2)$$

Glassy disilicate gives reproducible pressures in the further inversion ranges which correspond to an equilibrium with metasilicate. The temperature relations are as follows:

t (°C)	706	730	785	813	850	865	895	918	950
p (mm)	21	34	73	126	187	267	426	705	940

The pressures are established quickly and, in fact, in 3 to 48 hours. Before these reproducible pressures, which are also obtained with the disilicate, higher pressures were obtained in each case which corresponded to the bivariant equilibrium. With conversion of crystalline disilicate up to an 18 per cent metasilicate formation, these pressures in the temperature range 450 to 600° depend on the ratio of the $K_2Si_2O_5/K_2CO_3$ mixture and can reach a height of 400 mm. In the range 18 to 24 per cent metasilicate, the pressure is independent of the ratio of mixture and has the following values:

t (°C)	670	735	785	845
p (mm)	65	100	176	517

In every case the equilibrium is reversible. The above monovariant equilibrium is the only one up to 960°. With carbonate, excess $K_2Si_2O_5$ crystallizes out. K_2CO_3 is observed in the monovariant equilibrium only up to 40 per cent disilicate, then the system is again bivariant.

The bivariant equilibria are determined by the appearance of melts which are saturated towards only one kind of crystal.

If one dissolves SiO_2 in such quantities in K_2CO_3 that homogeneous melts result, then reaction according to the above equilibrium takes place in a pure CO_2 atmosphere at 898, 956, and 998°. Nevertheless, only half the equivalent CO_2 quantity is driven off when two SiO_2 molecules react with one K_2CO_3. The resulting $K_2Si_2O_5$ can be identified optically after cooling the melt. Since the primary action of SiO_2 according to the unstable equilibrium $K_2CO_3 + SiO_2 = K_2SiO_3 + CO_2$ takes place, then the $K_2Si_2O_5$ is formed by CO_2 absorption of the metasilicate or by the reaction of the metasilicate with SiO_2. With increasing carbonate excess, the percentage of disilicate decreases as shown by the data in the following table:

Molecular ratio	1537	960	541	326	238	110	80
Inversion	68.4	78.1	72.8	66.9	63.5	53.7	42.3

(Molecular ratio is moles K_2CO_3 to 100 moles $K_2Si_2O_5$ Inversion is $K_2Si_2O_5$ in mol per cent)

The $K_2Si_2O_5$ decreases with increasing temperature. The influence of CO_2 pressure on this equilibrium is very small. It, therefore, requires higher pressures in order to increase the concentration of CO_2 in the melted K_2SiO_3 so strongly that the inverse reaction takes place. At 1100°, and a CO_2 pressure of 750 atmospheres, there takes place a 7.5 per cent CO_2 absorption (equal to a 24.65 per cent carbonate formation). This corresponds to a 63 per cent conversion of metasilicate.

$$3.\ K_2SiO_3 + K_2CO_3 \rightleftarrows K_2SiO_4 + (CO_2)$$

The equilibrium resulting from the action of K_2CO_3 on K_2SiO_3 is very dependent on the ratio of silicate to carbonate. Reproducible pressures could be observed only with the molar ratio 2:1 which was obtained by the conversion of glassy disilicate. These pressures are reversible and have the following temperature relationship:

t (°C)	908	968	1005	1035	1050
p (mm)	44	103	323	567	754

With glassy metasilicate in the ratio 1:1, higher initial pressures can be measured but not with crystalline metasilicate. The pressures quickly fall to the above values.

The pressures establish themselves within a few hours and are reversible. Simultaneously there is a considerable volatilization of K_2O.

The Unstable Equilibria

$$1.\ [SiO_2] + [K_2CO_3] \rightleftarrows [K_2SiO_3] + (CO_2)$$

Even the action of quartz on K_2CO_3 leads to the formation of metasilicate compounds in the range 300° to 600°. At higher temperatures an increasing amount of disilicate appears. The metasilicate formation is independ-

ent of the ratio of the raw materials. The temperature reaction-pressure relations are given in the following table:

t (°C)	446	475	513	557	567
p (mm)	49	111	220	571	986

The pressure is established in about 100 to 400 hours. With mixtures of 2 carbonate:1 SiO_2 there is a greater speed than with ratios 1:1 and 1:2. The pressures are reproducible, but at high conversions do not attain the above values.

7. The System Na_2O—SiO_2—CO_2

(*a*) *Na_2O—SiO_2.* Fig. 4 gives the melting diagram according to D'Ans and Löffler. There occur four congruent melting compounds: Na_4SiO_4, $Na_6Si_2O_7$, Na_2SiO_3, and $Na_2Si_2O_5$. Melts stronger in Na_2O than the orthosilicate attack the platinum containers so strongly that an investigation is not possible. The parts of the diagram which are rich in Na_2O, are, therefore, hypothetical. The eutectic between ortho- and pyro-silicate at 960°. 36.5 mol per cent SiO_2 is apparently not established with sufficient accuracy because of the still problematic α—β conversion of orthosilicate. The eutectic between pyro- and meta-silicate lies at 1015° and 45.5 mol per cent. SiO_2. According to Kracek, the diagram between ortho- and meta-silicate takes another course. According to him, pyrosilicate does not occur, and the eutectic between Na_4SiO_4 and Na_2SiO_3 lies at 1022° and 43.1 per cent SiO_2. The eutectic between meta- and di-silicate was found by Morey and Bowen at 840° and 62.5 mol per cent SiO_2. The eutectic between quartz and disilicate lies at 793° and 74.6 per cent SiO_2.

The density of Na_2O—SiO_2 melts at 1000° to 1400° has been measured. The values obtained are given in the following table:

Na_2O (%)					
20	t(°C)	987	1146	1248	1304
	d	2.270	2.250	2.240	2.230
30	t(°C)	1004	1150	1252	1400
	d	2.270	2.250	2.230	2.205
45	t(°C)	1044	1170	1284	1413
	d	2.260	2.240	2.210	2.190
55	t(°C)	1105	1208	1305	1412
	d	2.245	2.215	2.190	2.165

The viscosities, which were measured by means of the swing and the ball viscosimeters over a rather large range of temperatures and concentrations of the Na_2O—SiO_2 melts, are as follows:

Na_2O %	Viscosity in C. G. S. (Poise) 1100°	1200°	1300°	1400° C.
15	—	—	1060	450
25	1360	500	200	96
35	440	166	68	33
45	63	25	10.5	5
50.8	9.8	4.7	2.5	1.5
55	3.7	1.6	1.0	0.7
60	1.0	0.6	0.4	0.3

The volatilization from the Na_2O—SiO_2 melt is less with high alkali contents at 1400° than from K_2O—SiO_2 melts. In relation with Na_2O content, the following vapor loss was found in 20 hours for every - cm^2 of surface:

Na_2O %	48.8	44.5	39.3	32.9	22.7	17.6	11.8
Loss (mg/cm^2)	52	35	19	7	5.8	3.8	2.5

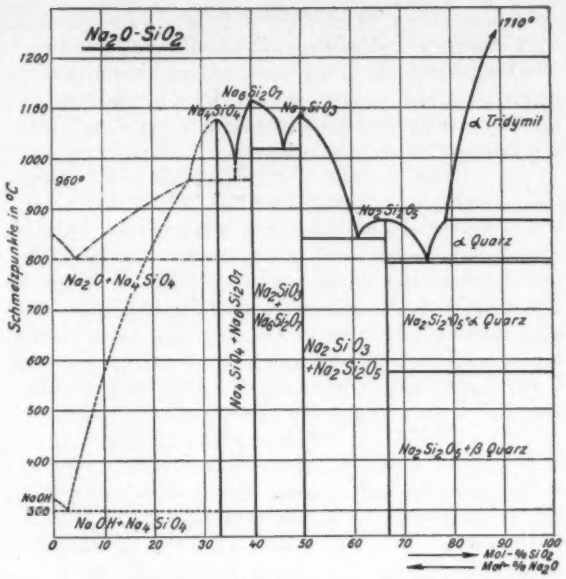


Fig. 4. Na_2O-SiO_2 melting diagram (D'Ans and Löffler).

Na_4SiO_4. Melting point 1078°. The orthosilicate is decomposed at 1118° into Na_2O and a melt with 40.7 per cent SiO_2. Inversion point α to β modification 960°.

β—Na_4SiO_4 has a sp. gr. of 2.5, forms optically biaxial crystal plates, refractive index $\eta = 1.536$. Refractive numbers: $\gamma = 1.537$, $\alpha = 1.525$.

$Na_6Si_2O_7$: Melting point 1115°, sp. gr. d = 2.96, crystallizes in plates, optically biaxial negative. Refractive index $\alpha = 1.524$, $\gamma = 1.529$.

Na_2SiO_3: Melting point 1089°. Forms needles, optical character negative. Refractive index $\alpha = 1.513$, $\beta = 1.520$, $\gamma = 1.528$. Soluble in water.

$Na_2Si_2O_5$: Melting point 874°. The compound has an inversion point at 678° and is capable of taking up Na_2O and SiO_2 with the formation of mixed crystals. The mixed crystals decompose on cooling to 706° and 768° respectively. $Na_2Si_2O_5$ forms scaly crystals, plates and needles and has optically negative characteristics. The refractive index for sodium light is $\alpha = 1.500$, $\beta = 1.510$, $\gamma = 1.515$. Is decomposed by water with difficulty.

$Na_2Si_3O_7$: Is stable only as glass.

(*b*) *Na_2O—SiO_2—CO_2.* Sodium silicate does not react at temperatures from 20° to 455° with CO_2. Equilibria with silicates rich in SiO_2 also do not occur. On the other hand, there has been observed a CO_2 absorption of homogeneous molten disilicate at 1150° which increased with rising CO_2 pressure from 0.4 per cent with 350 atmospheres to 2.5 per cent with 800 atmospheres. This CO_2 absorption is caused by dissociation of $Na_2Si_2O_5$ present in the melt into Na_2SiO_3 and SiO_2 so that Na_2CO_3 molecules can exist in the melt alongside SiO_2 molecules. The following table gives the results at 1150° and a CO_2 pressure of 750 atmospheres:

% SiO_2 in the Original Melt						
49.2	55.0	62.0	64.0	65.9	70.0	72.7
% CO_2 in the Final Melt						
6.5	4.5	3.0	2.8	2.5	1.7	1.2

The Stable Equilibria

1. $Na_2Si_2O_5$ Na_2CO_3 2 $Na_2SiO_3 + \rightleftarrows CO_2$

With the reaction of disilicate with carbonate, a series of bivariant and monovariant equilibria occur from 500° to 1000°. Starting with the molecular ratio of 1:1, the following pressures are observed:

t(°C)	433	515	573	609	635
p(mm)	12	50	194	371	540

which decrease with advancing conversion. This bivariant equilibrium corresponds to the formation of a ternary carbonate mixed crystal. When the composition 0.33 $Na_2Si_2O_5$, 0.33 NaO_2, 0.33 Na_2SiO_3 is reached, then there is saturation of mixed crystal, and the following monovariant equilibrium sets in:

(*a*) $[Na_2Si_2O_5] + [Na_2CO_3] \rightleftarrows 2\,[Na_2SiO_3] + (CO_2)$.

The corresponding pressures are:

t(°C)	641	658	668
p(mm)	232	324	392

The pressures are reproducible up to a composition of 0.17 $Na_2Si_2O_7$, 0.17 Na_2CO_3, 0.66 Na_2SiO_3. It is established within 50 to 200 hours. Then the pressures decrease with further increasing degree of conversion. Above 760° to 840° a double saturated carbonate melt takes part in the equilibrium, so that once more reproducible pressures are observed in certain ranges from a composition 0.22 $Na_2Si_2O_5$, 0.22 Na_2CO_3, 0.56 Na_2SiO_3 on, which belong to the monovariant equilibrium.

(*b*) $[Na_2Si_2O_5] + melt \rightleftarrows 2[Na_2SiO_3] + (CO_2)$. The pressures are:

t(°C)	770	775	775	780	770	790	785
p(mm)	310	318	344	359	373	529	450

Since in this equilibrium saturated mixed crystals take part, the pressures do not always have the same values. It is established in 20 to 300 hours according to the quantity of melt phase.

The pressures are reversible. Also, in a pure Na_2SiO_3 the CO_2 absorption in this temperature interval becomes static at 793° and 486 mm within 59 days.

In close connection with this equilibrium, the following pressures on the conversion of glassy disilicate were observed:

t(°C)	540	580	625	730	770	790	804
p(mm)	40	63	108	297	496	734	1015

These pressures are reproducible in a wide range, even with carbonate excess. They are established in 50 to 200 hours, with a molecular ratio of 1:2 carbonate in 30 to 100 hours. At first, higher pressures were observed, which perhaps correspond to the equilibrium (a).

(*c*) $[Na_2CO_3] + melt \rightleftarrows 2[Na_2SiO_3] + (CO_2)$. If the conversion of mixtures rich in carbonate, such as 0.17 $Na_2Si_2O_5$, 0.5 Na_2CO_3, 0.33 Na_2SiO_3, are followed, then there are observed, up to 760° with increasing inversion, varying pressures of the order of magnitude up to 200 mm, which correspond to the bivariant equilibrium [Na_2SiO_3], [Na_2CO_3] and (CO_2). Above 850°, higher pressures were established, which correspond to the bivariant equilibrium [Na_2SiO_3], melt, (CO_2). From about 0.1 $Na_2Si_2O_5$, 0.43 Na_2CO_3, 0.47 Na_2SiO_3 up to complete conversion there are observed, however, the reproducible and reversible pressures of the monovariant equivalent (c).

t(°C)	817	834	850	868	880	915	945	970	985
p(mm)	46	68	90	120	156	277	357	566	644

The pressures are established in 8 to 25 hours and because of the appearance of saturated mixed crystals do not always reach the same height.

2. $2\,Na_2SiO_3 + Na_2CO_3 \rightleftarrows Na_6Si_2O_7 + CO_2$

$Na_6Si_2O_7 + Na_2CO_3 \rightleftarrows 2\,Na_4SiO_4 + CO_2$

In the reaction of meta- and pyro-silicate with carbonate, melts take part. The equilibria are, therefore, bivariant in a wide range and monovariant only in narrow limits. The appearance of these bivariant and monovariant equilibria does not correspond, however, to a simple eutectic type of the partial systems Na_2SiO_3-Na_2CO_3-$Na_6Si_2O_7$ and $Na_6Si_2O_7$-Na_2CO_3-Na_4SiO_4. It is, therefore, evident that higher-melting mixed crystals, or, as the case might be, carbonate compounds are formed.

$Na_2SiO_3 + Na_2CO_3 \rightleftarrows Na_6Si_2O_7 + CO_2$:

t(°C)	918	936	951	980	1032	1060
p(mm)	21	44	80	115	215	320

Somewhat higher pressures were observed at first.

$Na_6Si_2O_7 + Na_2CO_3 \rightleftarrows 2\,Na_4SiO_4 + CO_2$:

t(°C)	980	1040	1090	1108	1145
p(mm)	22	78	141	179	275

The pressures are established within a few hours, are reversible and in the latter case are reproducible within a 20 per cent limit.

The reaction of Na_2SiO_3 with Na_2CO_3 in homogeneous melts has been investigated by Niggli. The equilibria are then trivariant. The reactions follow the law of mass action. On solution of SiO_2 in Na_2CO_3 at 900° and 956° the per cent equivalent CO_2 loss with decreasing SiO_2 approaches the value of 200; that is, the SiO_2 molecule which enters goes completely to Na_2SiO_3, and this, in part, to a silicate of still higher alkali content, the limit being Na_4SiO_4. The mols of Na_2CO_3 which are still further decomposed by the Na_2SiO_3 formed in the mixture (designated in the table by U) are fairly constant for a given temperature and independent of the dilution and the Na_2SiO_3:Na_2CO_3 ratio. This is shown in the table:

Mols Na_2CO_3 to 100 mols Na_2SiO_3		1210	1050	790	610	560	420	290	270	190	180	133	102
U	898°	5.2	5.2	5.2	4.8	4.6	5.6						
	956°		6.6	7.0		7.5		10.1	9.3	10.5	9.9	10.5	11.4
Mols CO_2 to 100 mols Na_2SiO_3			82	69		60		44	40	41	38	35	34

We must assume that with concentrations up to 1:3 there are always formed in the homogeneous melts about 10.5 mols $Na_6Si_2O_7$ (at 956°) and that further conversion of this silicate to Na_4SiO_4 takes place only at higher dilutions. The sum of the mols of $Na_6Si_2O_7$ and Na_4SiO_4 formed is approximately constant; at 956° it amounts to 7 mols; at 898°, 5 mols.

The Unstable Equilibria

1. $[SiO_2] + [Na_2CO_3] \rightleftarrows [Na_2SiO_3] + (CO_2)$.

Independent of the ratio of the original materials the following pressures were obtained:

t(°C)	320	425	485	525	551	590
p(mm)	17	27	104	249	416	764

The reactions take place in the solid state and are strongly influenced by the resulting products of reaction, so that a regrinding of the mixture is always necessary. The pressure is established in 100 to 200 hours, with higher pressures up to 600 hours. After a certain conversion, the pressures are no longer reproducible, but decrease with increasing conversion.

2. $Na_2Si_2O_7$ (GLASS) + 2 $Na_2CO_3 \rightleftarrows$ 3 Na_2SiO_3 + (CO_2).

The compound $Na_2Si_2O_7$ is stable only as glass and with Na_2CO_3 gives the following pressures reproducible within wide limits:

t(°C)	626	692	744	805	830	840	880	896
p(mm)	15	41	74	192	294	330	715	779

The establishment of pressure corresponds to 20 to 50 hours according to the ratio of the mixture, with carbonate excess 100 to 200 hours and is only partially reversible, since the reversible reaction follows the stable meta/disilicate equilibrium.

8. The System CaO-SiO_2-CO_2

(*a*) *CaO-SiO_2.* [The equilibrium diagram is given in Fig. 5.] Among the congruent melting compounds occur 2 CaO.SiO_2 and CaO.SiO_2. The latter possesses a very flat melting maximum and hence considerable dissociation. The compound 3 CaO.2 SiO_2 melts incongruently, while 3 CaO.SiO_2 is formed by reaction in the solid state below 1900°. The eutectic between αCaO.SiO_2 and tridymite lies at 63 per cent SiO_2 and 1436°, that between αCaO . SiO_2 and 3 CaO . 2 SiO_2 at 45.5 per cent SiO_2 and 1455°. The third eutectic is formed between 2 CaO.SiO_2 and CaO at 2065°. Its composition is 32.5 per cent SiO_2, 62.5 per cent CaO.

Viscosity measurements of CaO.SiO_2 melts with 45.49 per cent and 54 per cent CaO have been published. They show, as illustrated in the following table, a distinct decrease in viscosity with temperature and rising percentage of CaO:

% CaO	Viscosity in poises at t°C			
45	t(°C)	1517	1573	1642
	poises	5.6	3.7	2.7
49	t(°C)	1547	1597	1647
	poises	3.0	2.3	1.8
54	t(°C)	1537	1566	1633
	poises	2.0	1.6	1.2

$Ca_3Si_2O_5$. 3 CaO . SiO_2 is stable only in the temperature interval from 1300° to 1900°. Below 1300° it decomposes into CaO and β-2 CaO.SiO_2 and with maximum speed at 1150° to 1200°. The presence of decomposition product accelerates the decomposition considerably. $Ca(OH)_2$, $CaSO_4$ also have an accelerating effect, apparently due to the formation of free CaO. On heating the components 3 $CaO(CaCO_3)$:1 SiO_2 to 1400°, the compound forms completely in 3 to 9 hours. In the presence of a little dicalcium ferrite the reaction is complete in 8 hours at 1450°.

Ca_3SiO_5 forms small, uniform grains of very weak double refraction. Optical character negative. Average index of refraction for sodium light 1.715. Sp. gr. 3.25. Possesses hydraulic properties.

Ca_2SiO_4: 2 CaO.SiO_2 melts at 2130°. On heating the two components 2 $CaO(CaCO_3)$:1 SiO_2 for three hours at 1300°, the compound is completely formed. By adding one per cent CaF_2, the speed is increased and takes place at a lower temperature. At 1300°, the formation is practically complete in one hour.

Inversion temperature $\alpha \rightleftarrows \beta$, 1420°; $\beta \rightleftarrows \gamma$, 675°. The volume effect of the latter inversion amounts to about 10 per cent. The β—γ conversion can be suppressed by the addition of 0.5 per cent Cr_2O_3; the α—β conversion by the addition of 8 mol per cent trialuminate on quenching from 1650°.

α2 CaO.SiO_2 corresponds to the mineral larnite, forms irregular, partly prismatic grains of strong double refraction, 0.023. Optical character positive. Index of refraction for sodium light $\alpha = 1.715$, $\beta = 1.720$, $\gamma = 1.737$. Sp. gr. 3.27.

β2 CaO.SiO_2 rounded grains often of prismatic shape, optically positive, average double refraction $\gamma - \alpha = 0.016$. Index of refraction for sodium light $\alpha = 1.717$, $\gamma = 1.735$. The α and β modification is distinguished only by the somewhat lower double refraction of the β form.

γ2 CaO.SiO_2 is obtained as a fine dust because of the large volume expansion of the β—γ conversion. Prismatic particles. Double refraction of about 0.015, negative optical character. Index of refraction for sodium light α=1.642, β=1.645, γ=1.654. Sp. gr. 2.974.

$Ca_3Si_2O_7$. 3 CaO.2 SiO_2 decomposes at 1475° into 2 CaO.SiO_2 and a melt with 44.5 per cent SiO_2. It crystallizes in rounded, irregular grains of rather weak double refraction ($\gamma - \alpha = 0.01$). Optical characteristic positive. Index of refraction in sodium light α=1.641, $\gamma = 1.650$.

$CaSiO_3$. Melting point 1540°. The inversion temperature of the α into the β modification lies at 1190°. The αCaO.Sio_2 can take up about two per cent CaO and SiO_2 with the formation of mixed crystals. On taking up CaO the conversion point is lowered to 1170°; SiO_2, on the other hand, causes a raising to 1210°. βCaO.SiO_2 can take up three per cent CaO and SiO_2 with the formation of mixed crystals.

αCaO.SiO_2 crystallizes into uniform grains. Index of refraction $\gamma = 1.654$, $\alpha = 1.610$. Strongly double refractive $\gamma - \alpha = 0.041$. Optical character positive.

βCaO.SiO_2, wallastonite. Sp. gr. d = 2.9163. Occurs in lathe shaped particles, optically negative. Index of refraction, sodium light: γ=1.631, β=1.629, α=1.616. Double refraction $\gamma - \mu = 0.015$. In a melt of $CaCl_2$ it is possible to find large crystals of this compound.

Course of reaction in solid state between CaO and SiO_2. At the surface of contact of a CaO crystal and a

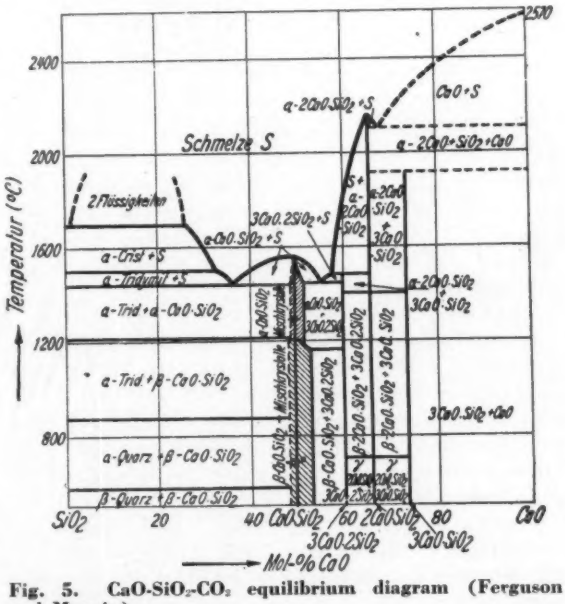


Fig. 5. CaO-SiO_2-CO_2 equilibrium diagram (Ferguson and Merwin).

SiO_2 grain there is first formed, under normal conditions over an amorphous skin, a thin crystal layer of orthosilicate. With a large excess of CaO and sufficiently high temperature, the diffusion of CaO goes through this crystal layer fairly quickly, so that at the orthosilicate/SiO_2 boundary a lower basic compound does not form at all, or only in small amounts. Below 1300° there is very little 3 CaO.SiO_2 formed. With lower CaO content or lower temperatures, free lime becomes scarcer in the boundary layer and there is the possibility of forming 3 CaO.SiO_2 and CaO.SiO_2. If all free lime disappears, then the diffusion of CaO goes from the orthosilicate direction more and more towards 3CaO.2SiO_2.

In the presence of water vapor, the course of the reaction remains the same, but the conditions for the formation of 3 CaO.2 SiO_2 are much better.

(*b*) *CaO-SiO_2-CO_2.* Calcium polysilicate does not occur. Hence, there is here a stable equilibrium between quartz and carbonate, which is not the case in the alkali system.

1. $[SiO_2] + [CaCO_3] \rightleftarrows [CaSiO_3] + (CO_2)$.

At 620° to 685° there are found pressures of 41 to 163 mm, which are considerably higher than the dissociation pressures of pure $CaCO_3$. The equilibrium pressures established after long times under the influence of water vapor and other catalysers are shown in the table:

t(°C)	312	416	486	536	560
p(mm)	8	55	105	502	734

The $CaSiO_3$ mixed crystals saturated with SiO_2 are formed. The pressures are reversible and are established in 150 to 300 hours. On higher conversions, especially with SiO_2 excess, the pressures decrease in spite of renewed grinding. Lower pressures were also observed when metasilicate takes up CO_2. Thus, at 545° there was a pressure of 260 mm. With a molecular ratio of 2 carbonate:1 SiO_2, the above pressures were obtained only up to 8 per cent inversion of the quartz, showing that the unstable equilibrium.

$$[SiO_2] + 2[CaCO_3] = [Ca_2SiO_4] + 2(CO_2)$$

goes over into the stable equilibrium

$$[CaCO_3] + 2[CaSiO_3] = [3\ CaO.2\ SiO_2] + (CO_2).$$

2. $2[CaSiO_3] + [CaCO_3] \rightleftarrows [3CaO.2\ SiO_2] + (CO_2)$.

The following temperature relations were observed:

t(°C)	374	576	618	669	678	682	690	702
p(mm)	32	105	137	301	233	334	443	586

The establishment of pressures occurs uniformly and corresponds to an average of 300 to 500 hours. They are reproducible with about 30 per cent carbonate conversion (in ratio of 1:1) and decrease in the conversion range 30 to 65 per cent. With a molecular ratio of 2 silicate:1 carbonate, sowewhat lower pressures were observed in every case.

3. $[3\ CaO.2\ SiO_2] + [CaCO_3] \rightleftarrows 2[Ca_2SiO_4] + (CO_2)$.

Proof of this equilibrium lies in the fact that CO_2 absorption by orthosilicate ceases at somewhat higher pressures than the $CaCO_3$ dissociation. Treating 3 CaO.2 SiO_2 with $CaCO_3$ gives the pressures shown in the following table in a conversion range up to over 50 per cent. With higher conversions, the pressures depend on the ratio of the phases present.

t(°C)	555	710	763	803	851
p(mm)	16	65	181	299	630

The pressures are established as quickly as the carbonate dissociation.

THE UNSTABLE EQUILIBRIA

1. $[SiO_2] + 2[CaCO_3] \rightleftarrows [Ca_2SiO_4] + 2(CO_2)$.

The pressures of this equilibrium, which is established mainly between 500° and 700°, have not been accurately established, since they fall in the range of the stable equilibrium, $2[CaSiO_3] + [CaCO_3] = [3CaO.2SiO_2] + (CO_2)$, and occur only when conditions prevent the establishment of the stable $SiO_2/CaSiO_3$ equilibrium.

t(°C)	500	523	529	662	697
p(mm)	53	74	93	157	334

2. $[CaSiO_3] + [CaCO_3] \rightleftarrows [Ca_2SiO_4] + CO_2$.

The pressures of this unstable equilibrium are not obtainable with accuracy, since they occur in the stable range of 3 CaO.2 SiO_2.

t(°C)	529	658	685	720	772	795
p(mm)	21	139	125	241	463	505

THE TICKNOR COLUMNAR CHECKER

An unfortunate typographical error occurred in the article entitled, "The Ticknor Columnar Checker," which appeared in the September issue of THE GLASS INDUSTRY. On page 338, column 1, line 16, the text reads, "show no *improvement* of checker action from this cause." This is incorrect. The word *impairment* should replace the word *improvement*. The entire sentence should read, "All operation data secured during the past few years on several tanks, however, show no *impairment* of checker action from this cause throughout the longest runs."

G. C. A. TO MEET IN ATLANTIC CITY

By a vote of more than two to one the Glass Container Association membership voted to hold their fall meeting at the Traymore Hotel, Atlantic City, N. J. The Board of Directors will meet on Wednesday, Oct. 26, and the membership will meet on the 27th and 28th.

GEORGE ROSS FORD, SR., 1882-1938

It is with regret that THE GLASS INDUSTRY records the death of George Ross Ford, Sr., retired glass manufacturer and grandson of Captain John B. Ford, founder of the plate grass industry in America. Son of the late Edward Ford, George Ford entered his father's factory as a young man and eventually succeeded him as president of the Edward Ford Plate Glass Co., which later merged with other interests to become the Libbey-Owens-Ford Glass Co. in 1930.

EDWARD MILLER, 1873-1938

Edward Miller, who was a pioneer in the manufacture of machinery for making glass, died at his home in Columbus, Ohio, on September 9th. Mr. Miller started his close association with the glass industry in 1900 when he was employed by the Federal Glass Co., where he later operated his own shop in partnership with R. J. Beatty. On the basis of his success in this enterprise, Mr. Miller organized the Miller Machine & Mold Works. In 1928, he organized the Miller Foundry Co., which he retained after disposing of his glass machinery business to the Lynch Corporation. Mr. Miller's contribution to the glass industry was a great and lasting one.

FLUORESCENCE ANALYSIS IN ULTRA-VIOLET LIGHT

By JULIUS GRANT, Ph.D., M.Sc., F.I.C.

Most of those who are engaged in the glass industry and familiar with its most recent advances are aware that under certain conditions many glasses can be made to emit a glow or fluorescence. The commonest applications of this phenomenon are in connection with the production of illuminating effects, frequently of a decorative nature (for example in the well-known colored discharge tubes); in such cases the glass is treated in such a way that when excited by the electric radiations, it develops a highly-colored fluorescence. There exists, however, a similar but less familiar application of this phenomenon, and this is the use of such fluorescence effects as a means of examining or identifying glasses. As a matter of fact, the principle of this method has now been applied extensively to other branches of industry and science; although, so far as the glass industry is concerned, it is believed that its possibilities do not yet appear to be as fully appreciated as they might be. It is therefore the purpose of this article to indicate some of the more interesting of them. In this sense the present article is thus complementary to that of P. Gilard, L. Dubrul, F. Jamar and D. Crespin.[1]

The Principle of This Method

The principle of this method is based on the fact that many substances (including glasses) which appear identical in ordinary visible light (for example in daylight or lamplight) fluoresce differently when compared in ultra-violet light. A source of ultra-violet is, therefore, required, in order that the test may be made. Now ultra-violet light is a form of radiation which differs from visible light only in the length of the waves, in which (according to the simplest, if not the most recent, theory) it is produced. This theory allows us to visualize waves of light as being generated in much the same manner as waves of water are generated when a stone is thrown into a calm pool. Radiations of different types may then be characterized by the distances between successive crests or troughs, these distances being known as the wave-lengths of the rays concerned. Examples are given below (1 Angstrom Unit denoted A, is 10^{-8} cm.):

	Approximately
Infra-red rays	4,000,000 to 8,000 A
Sunlight	10,000 to 4,000 A
Visible light	
Red rays	8,000 A
Green rays	6,000 A
Violet rays	4,000 A
Ultra-violet rays	136 to 4,000 A

It is thus apparent that sunlight overlaps the infra-red range at one of its ends and the ultra-violet at the other, although it does not include very much of the latter. The portion that it does include enables sunlight to be used for photography and "sun-bathing," and to some extent for the production of the fluorescence. Its infra-red ray content is larger, and is responsible for its heating effects. For the sake of completeness, it may be mentioned that at wave-lengths greater than those of the infra-red range we have long waves such as those used for transmission by radio; while below the ultra-violet range come the *X*-rays, and eventually the cosmic rays which are believed to be only 0.0005 A in length.

Apparatus

Although sunlight contains ultra-violet light, it is seldom used in practice for the production of fluorescence, as it does not contain a very high proportion of radiations capable of this. It is preferable to use an electric-discharge produced between electrodes composed of substances such as carbon, mercury or tungsten. For reasons into which we cannot enter here, mercury is to be preferred, and a good deal of the pioneer work on the method was carried out with lamps of this nature. In one popular form, which was developed chiefly in connection with "artificial sun-ray" treatment, two reservoirs of mercury in quartz containers were joined together by means of a quartz tube. When the reservoirs were connected to the electric mains and the whole system tipped up at an angle, mercury ran from one reservoir to the other thus causing a short-circuit which generated sufficient heat to convert some of the liquid mercury into mercury vapor. This vapor was formed in the tube connecting the reservoirs, and served as a medium through which the arc discharge between them could pass, and this was the source of the ultra-violet light.

In a more recent and improved form[2], the necessity for tipping the lamp is eliminated, the electrodes being metal cups coated with salts of the rare earths in a quartz tube containing a rare gas (argon) and a very small quantity of mercury; when the electrodes are connected to the electric mains, the rare gas serves as an activator and the arc strikes of its own accord. The advantages of this method from the points of view of convenience in use and transport are obvious; in addition, since no liquid mercury is used, the shape of the lamp is less restricted—a matter of importance in some of the applications of fluorescence analysis. The latest development is a lamp having the form of an ordinary electric light bulb, which fits into the standard lampholder and gives an intense source of ultra-violet light.

It is apparent from the figures given above for the various wave-length ranges that the wave-lengths of the longest of the radiations in the ultra-violet range is less than that of the shortest of the visible radiations. From this fact it will be realized that true ultra-violet light, whether from the sun or produced by one of the methods described above, is invisible. This is an important point, because the mercury discharge contains a large propor-

[1] The Glass Industry, 1938, *19*, 99.
[2] See J. Tutin, Elec. Rev., 1 and 22, Feb., 1935.
[3] See J. A. Radley and J. Grant, "Fluorescence Analysis in Ultra-Violet Light," London, 1935.
[4] *Compte Rend.*, Paris, 16 Nov., 1936.
[5] See W. R. Lester, The Glass Industry, 1931, *12*, 83.
[6] *Jour. Amer. Chem. Soc.*, 1935, *55*, 593.
[7] *Glastechn. Ber.*, 1932, *10*, 80.
[8] Loc. Cit. & *Verre Silic. Ind.*, 1937, *8*, 414.
[9] See N. A. Marris, *Analyst*, 1934, *59*, 686.
[10] See especially J. J. Rorimer, "Ultra-Violet Rays and Their Use in the Examination of Works of Art," New York, 1931.
[11] Cf. Radley and Grant, loc. cit.

tion of visible light as well as of ultra-violet light, and unless the former is removed, the fluorescence produced by the latter cannot be seen. Sunlight provides an example of this, because everyday objects around us are continually fluorescing owing to the ultra-violet light from the sun, although we are quite unaware that this is happening because it is masked by the excess of visible light.

Filter Glasses

Separation of visible and ultra-violet light is very simply achieved in practice by the use of appropriate filters, and the development of glasses for the purpose is one of the most important contributions of the glass industries towards improving the technique of the method. One of the best-known glasses for the purpose is the result of the pioneer work of R. W. Wood so long ago as 1910. Modifications of it are sold under a number of trade names, but the essential feature is the inclusion of nickel oxide, which may vary in quantity from 0.5 to 12 per cent. The chief ingredient is silica, which may amount to 50 per cent but about 20 per cent each of barium and potassium oxides are usually also present, together with about 10 per cent of nickel oxide, and about 1 per cent of copper oxide, the special purpose of the last being to cut out the red radiations. Lenses of quartz coated with silica are also used, but these are less satisfactory.

Such a glass appears almost black and opaque in ordinary light, but when viewed through it the mercury vapor lamp has a dull, reddish glow. This is due not so much to the transmission of visible light as to the fluorescence (in the transmitted ultra-violet light) of the vitreous humor or other substances present in the eye itself. The amount and nature of the light which can be seen in this way varies from one individual to another, and in particular according to the age of the person concerned; some workers believe that, within limits, it is possible to ascertain the age of an individual from the type of light he is capable of seeing.

Filters of this type are of course complementary to the more familiar kind used for removing ultra-violet light and allowing the passage of visible light. Crookes' glass is of course the best known of these, and colored glasses have also been used. Metals such as cerium, titanium and vanadium, especially in the oxidized state, appear to be specially effective in this respect. The degree of oxidation is also of particular importance when iron is present, because iron in the ferrous state involves a much poorer absorbency towards ultra-violet light than does ferric iron, and it may be that the slow oxidation of iron from the ferrous to the ferric state may account for the changes which sometimes occur in such glasses in the course of time. Window glass has poor powers of transmission for ultra-violet light.

These points are mentioned, partly because it is believed that they will be of interest to those connected with the glass industry, and partly because they have an important bearing on the production of ultra-violet light, whether for the production of fluorescence or for "sun-ray" treatment. They explain, for example, why quartz which transmits ultra-violet light as well as resisting relatively violent changes in temperature without cracking, is used for ultra-violet lamps instead of ordinary glass; and they also enable a selection of glasses to be made for the protective goggles which are essential when exposure of the eyes to ultra-violet light for any length of time becomes necessary.

Applications

We may now pass on to some of the applications of the method in connection with the glass and allied industries, references being made eleswhere for fuller details[3]. It may, however, first be mentioned that the technique of operating the test is very simple indeed, the glass being exposed in filtered light from the lamp (preferably in a darkened room), and the color and intensity of the resulting fluorescence observed. Usually the glass is examined in the form of a large piece, both the surface and edge being inspected, although in some cases additional information is provided by the use of the powdered material.

The author has examined many glasses in this way, but has seldom found two of markedly different compositions which have the same fluorescence. Sometimes the difference is one of intensity and sometimes of color: in the latter case the difference may be a subtle one, but it is always apparent to the unaided eye and it is always reproducible for the same glass. Unfortunately, it is not yet possible to say what determines the nature of the fluorescence seen. There is a certain amount of evidence that it is dependent on the physical structure of the glass; thus, P. Curie[4] found that a zinc borate glass containing manganese oxide fluoresced when wholly crystalline, but not in the vitreous state. On the other hand, the author is inclined, as a result of his experiments, to favor the view that in general the principal factor is the chemical constituents present. Probably both theories have an element of truth, but the latter is in line with a fact which has been established in many other connections, namely that small quantities of certain constituents have a very pronounced effect on the fluorescence.

When more work has been carried out on this point some interesting results will doubtless be obtained, and the value of the method as an instrument of analysis will be increased considerably. Even up to the present, however, it has been possible to arrive at some useful generalizations. Thus, for example, "protective" glasses of the Crookes' type always (that is, within the author's experience) show a characteristic vivid blue-white fluorescence. Specific tests for most of the elements which occur in glass, based directly or indirectly on the fluorescence produced are also available, and it is possible to differentiate between glasses colored with selenium and with manganese[5]. It has been found, moreover, that when certain metals are present, the intensity of the fluorescence varies according to the proportion of one in relationship to the other. Thus, B. E. Cohn[6] showed that with borate glasses the intensity of the fluorescence is a maximum when the ratio of the zinc content to the manganese content is as 23 is to 1. The presence of rare earths or of uranium or zirconium compounds also has a considerable influence on the nature of the fluorescence. In fact, F. Eckert and K. Schmidt[7] found that the intensity of the yellow-brown fluorescence of glass due to the presence of cerium could be used to measure the proportion of this element present. The same workers also studied the effects on the color of other metals in the glass.

In some cases the fluorescence is developed only after a period of exposure to x-rays or to ultra-violet light itself, and this phenomenon provides an additional means of identification. A useful application of the method, of a similar nature, is to the raw materials used in glass manufacture; in many cases an examination of these in ultra-violet light will reveal a deviation from standard so far as composition or purity is concerned. G. Dubrul, F. Jamar and D. Crespin[8] showed that sodium or potassium silicate glasses do not fluoresce if barium or magnesium is present, and the latter only fluorescence if calcium, zinc or aluminum is present. Lead, cobalt, manganese, sulphur, selenium and boron all induce fluorescence, the color of which in the three last instances depends on the nature of the other elements present. Arsenic, antimony, tin, iron, chromium and nickel, however, are inactive.

A very important application of the method is in the identification of glasses. A manufacturer is sometimes called upon to identify his own glass, for example in connection with a complaint. This is sometimes a very difficult matter, and even a full chemical analysis with all the labor and difficulty it involves frequently fails to settle the matter. Since, however, so few glasses appear alike in filtered ultra-violet light, a very rapid and certain method is thus provided, especially if reference samples, against which returned specimens may be compared, are retained. Some manufacturers make a point of adding an ingredient to their glass which gives it a characteristic fluorescence without, however, affecting the other properties, including its appearance in visible light. This is facilitated by the fact that certain substances in very low concentrations can provide the desired effect.

One very interesting application of this kind is in connection with criminological work, and two examples will suffice to illustrate it. In one case the question arose whether a certain car, whose headlamps were smashed, had been involved in a particular road accident. Comparison in ultra-violet light of the glass remaining in the lamps with some pieces found in the road on the scene of the accident showed that the two fluorescence effects were identical, and this fact played a valuable part in enabling the cause of the accident to be traced. Similarly[9] in an instance where an attaché case was thrown into a shop window in a "smash and grab" raid, it was possible subsequently to identify the glass from the window with some splinters from the case.

Applications to museum work have also been devised[10]. Thus, imitation of ancient glasses by surface treatment, repairs, and restorations may be detected because it is most unlikely that materials showing identical fluorescence effects would be used for the original and for the forgery. Moreover, as indicated above, ageing produces changes in glass, which are reflected and even magnified by changes in fluorescence.

The method cannot be pursued further here, although applications to many industries allied to glass manufacture (*e.g.*, ceramics) as well as to other branches of industry also exist.[11]

• The August, 1938, issue of "Priorities," house organ of the Prior Chemical Corporation, New York, contains an interesting thumb-nail sketch of glass. Although starting back in the 13th century, the article loses no time in getting down to the most modern developments.

Dedicating the Glass Center Building for the 1939 New York World's Fair. William E. Levis, president of Owens-Illinois Glass Co., is placing a glass block in the cornerstone. Standing are Amory Houghton, president of Corning, and H. W. Wherrett, president of Pittsburgh Plate. Grover Whalen, president of the Fair, is in the foreground. Sealed within the blocks were four forecasts on glass cloth of the number who would attend the building. Whalen's guess, 61,505,275 persons; Houghton's, 52,500,000; Wherrett's, 47,500,000; and Levis', 46,000,000.

PRODUCTION FIGURES FOR THE GLASS INDUSTRY DURING AUGUST

Glass Containers: Production of glass containers during the month of August, 1938, was 4,031,299 gross, bringing the 1938 total to 28,350,885 gross. Shipments during August were 4,178,005 gross, bringing the 1938 total to 28,922,537 gross.

Plate glass: The total production of polished plate glass by member companies of the Plate Glass Manufacturers of America during August, 1938, was 7,676,078 sq. ft., as compared to 5,505,768 sq. ft. produced by the same companies in the preceding month, July, and 17,898,064 sq. ft., produced in the corresponding month last year, August, 1937.

Window glass: During August, 1938, the production of window glass was 433,877 boxes, which represents 26.7 per cent of industry capacity. As compared with this, August, 1937, production was 1,351,948 boxes, representing 83.4 per cent of industry capacity.

REFRACTORIES SCHOLARSHIP AT ALFRED

The Electro Refractories & Alloy Corporation, Buffalo, N. Y., has recently made arrangements with Dean M. E. Holmes of the New York State College of Ceramics at Alfred, for maintaining a scholarship which represents a marked departure from the usual policy regarding university scholarships. Whereas most scholarships are granted only to graduate students, this scholarship is to be granted only to senior students.

Purposes of the scholarship are to develop closer working contact between the college and industry, whereby the industry will be more of a factor in shaping educational policies, to emphasize research on refractories, to render financial help to needy students and to get some research work done which is needed by the industry and which can best be done in a university.

GLASS NEWS FROM ABROAD

Czechoslovakia: Exports of glass have suffered a sharp decline. 1937 showed a 33 per cent gain over 1936, but during the first six months of 1938, all of these gains were lost and more. Hollow ware declined 9.7 per cent, pressed glass 19 per cent, and Gablonz fancy glassware 23.8 per cent. Bottle exports were up by 67.8 per cent. The falling off was general in all markets except the United States, where the reciprocal treaty increased exports substantially. The above figures cover the first six months of the year. Since then the political situation in Czechoslovakia has clouded the entire economic situation, with exports dropping still further. Trade in bottles with Italy has practically disappeared.

Messrs. Fischmanns Sohne A. G., Prague, is erecting a new glass factory in Tischau, near Teplitz-Schonau. Reports do not state the type of ware to be manufactured.

Finland: Considerable expansion is taking place. A large factory for making window glass, established in 1935 by the Finska Glasfabriks Aktiebolag, has been enlarged several times and now will add a department for the production of plate glass. The capacity production of 20,000 square meters of ground and polished plate glass is more than double the annual Finnish consumption.

The Lahden Lasitehdas Osakeyhtio glass works has been modernized, and the new equipment almost doubles the plant's production of window glass. A plate glass department has been added capable of producing sheets of large dimension.

These improvements should take Finland permanently out of the market as a buyer of window and plate glass and makes her a definite factor in the export market.

A snapshot taken by Hugh L. Kline of the Corhart Refractories Company on August 19th. It shows the unloading of Czechoslovakian glass from the North German Lloyd steamer, New York, just after it had docked in New York.

Hungary: A new glass factory is being erected in Hajduszobozlo. The Price Commissar has ordered a reduction of four per cent in the price of green glass bottles.

Italy: Government efforts to control the glass industry have failed. Agreements imposed upon the manufacturers and distributors have been abolished, leaving both sides free to negotiate between themselves.

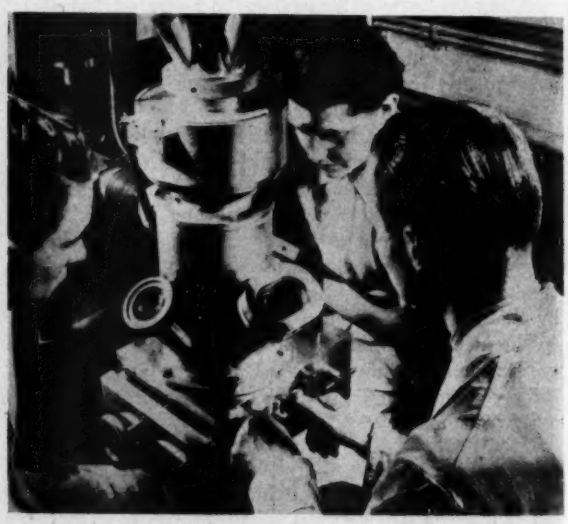
Norway: Norway is now in the throes of the bottle-breakage lawsuit business. An exploding seltzer bottle caused a consumer to lose an eye. The jury acquitted the glass company of any negligence after it had demonstrated that a regular testing procedure was employed as a precaution against bottle failures.

Palestine: Efforts are being made to cartellize the Jewish glass industry. Nine firms in Haifa have united to form the single firm of Zekhukhit Raava (Crystal Glass), and in Jerusalem seven window glass companies have united to form the Halon Raava (Window Glass).

Poland: A new company has been formed in Petrikau to erect a factory in the newly developed central industrial district for the production of unbreakable glass. It is expected that the new factory will supply the whole of Poland's demand for this type of glass.

FIVE-FOOT MICROSCOPE MAGNIFIES 100,000 TIMES

Drs. Ernst Ruska and Bodo Von Borries have constructed a five-foot microscope with a 100,000 magnification, which permits more than one person to view the object. Inside the tube is a vacuum. The electrons are focused by the electrical field of the coils inside and make an image of the object they reflect. This is converted into ordinary light by the electrons striking a flat glass coated with chemicals. The fluorescent light from the chemicals shows exactly the pattern made by the electrons.



Laboratory assistants getting acquainted with the new microscope in a Berlin hospital.

EQUIPMENT AND SUPPLIES

NEW LINE OF COLORS FOR BOTTLE DECORATION

The O. Hommel Co., Pittsburgh, manufacturers and marketers of ceramic colors and chemicals for nearly half a century, are now ready to present to the glass container industry a new and complete line of acid and alkali resistant colors. The company has recently completed months of extensive research in its laboratories, at which time, every conceivable test was applied to these colors before they were given to the industry as the most acid and alkali resisting colors now available. Of the numerous tests completed, the most convincing was a test made using the exact same washing compounds that are now being used commercially in cleaning milk and beverage bottles after public use.

These new acid and alkali resisting colors are reported to mean an appreciable savings to the glass container industry. The new Hommel line of colors, as shown in actual tests made, was found to be three times more resistant to acid and alkali than any other color material now on the market. The O. Hommel Co. will gladly send samples of these new colors to anyone directly interested.

STEARNS IMPROVED MAGNETIC PULLEY

The Stearns Magnetic Mfg. Co., Milwaukee, has recently announced improvements in its High-Duty magnetic pulley. The former features that have characterized this magnetic pulley have been retained, including the one-piece casting, but to allow for greater radiation area, a new ribbed construction has been designed which includes deeper coil pockets for additional ampere turns of wire. Another added feature includes specially designed air ducts which have been improved so that circulation of air is forced around the coils by the action of the belt on the pulley. Stearns magnetic pulleys are furnished in a wide range of diameters and face widths to accommodate various existing conveyor systems, and are particularly adapted for removing tramp iron from glass batch.

LANCASTER APPOINTS

James K. Martin has been appointed assistant manager of the Lancaster Iron Works, Inc., Lancaster, Pa., effective September 1st. He is a grandson of Henry Martin, inventor of the Martin sand molded brick machines and is the third member of the family affiliated with this organization. Mr. Martin comes to Lancaster after having been affiliated with the sales department of the Hershey Chocolate Corporation for many years.

NEW ASKANIA RATIO METER

A new direct-reading ratio meter is an unusual and practical development in instrumentation recently announced by the Askania Regulator Co., 1603 South Michigan Ave., Chicago, Ill. Arranged to show at a glance the relationship between fuel and air, the ratio meter may

be used on all types of heating equipment, whether equipped with automatic fuel-air ratio control or manually operated.

The new instrument incorporates two flow-metering elements, one for air and one for gas. The indicating pointers are arranged to cross in the chart area in the center, the point of intersection of the pointers indicating the relationship between the two flows. As long as the pointers cross on the vertical zero line, the indication is that a neutral flame is being maintained. If they cross in the area to the right of the zero line, excess air is indicated and the percentage of excess air is shown. Conversely, a crossing of the pointers in the air deficiency area to the left shows the amount of such deficiency.

The manufacturer states that the crossing pointer principle can also be adapted to other conditions to show the relationship of two variables. A descriptive bulletin is available.

BULLETINS RECEIVED

Bailey Meter Co., Cleveland, Ohio. A 32-page bulletin entitled "Bailey Meter Control" describes the application of steam-flow-air-flow automatic readjustment type of air-operated combustion control. Also explains fundamental principles involved in controls, both for boilers fired with stokers and for boilers fired with fuels in suspension.

The Fairbanks Co., 393 Lafayette St., New York. Catalog 54-75 illustrates and describes a complete line of wheelbarrows for practically all purposes.

Grobet File Corp. of America, 3 Park Place, New York. Illustrates more than 200 different kinds of rotary, hand cut, rasp cut and milled cut files.

International Filter Co., 59 East Van Buren St., Chicago, have issued a new bulletin, "Infilco Hot-Flow Water Softeners for Boiler Feed Water Treatment," which points out that their equipment provides the mechanical means for chemically treating water heated to practically steam temperature.

POWER SHOW, DEC. 5

The Thirteenth National Exposition of Power and Mechanical Engineering (the Power Show) will be held this year at Grand Central Palace, New York, during the week of December 5. It is said that more than 250 leading manufacturers have already engaged exhibit space. As heretofore, the Exposition is under the management of the International Exposition Co., Grand Central Palace, New York. Charles F. Roth, president, is in charge.

NEW PRESSURE CONTROLLER

The Brown Instrument Co., Philadelphia, has announced the development of their Air-O-Line furnace pressure controller, which is applicable for controlling any pressure in the range from $-5.0''$ H_2O to $+5.0''$ H_2O. It is essentially a sensitive, inverted bell-type draft indicator combined with the well-known Brown Air-O-Line control unit. Automatic reset and fully adjustable throttling range prevents the furnace pressure from lining out at some point other than the control point and eliminates over-correcting and cycling.

This instrument is reported to have consistently held furnace pressures within plus or minus .002 inches of water on a scale spun of 0.2 inches of water. This instrument is further said to be not only accurate but instantaneous as the pointer will move 10 per cent of the total range in one second and 100 per cent of the total range in three seconds.

It is adaptable for installation on all types of furnaces, stills, kilns, ovens and other similar equipment where very low differential or static pressure must be maintained.

HIGH TEMPERATURE LUBRICATION

Acheson Colloids Corporation, Port Huron, Mich., recommends fortification of oils with Oildag for difficult high temperature jobs and Aquadag as a dip material for glass working tools. They state that thin homogeneous films of graphite capable of withstanding temperatures up to 5,000 degrees F. in inert atmospheres are formed on friction parts by the consistent use of "dag" colloidal graphite. Acheson claims that their ability to function as dry lubricants long after plain oil films have oxidized indicate the immense value of these lubricants to the glass industry.

CURRENT PRICES OF GLASS-MAKING MATERIALS

FURNISHED BY PRODUCERS, MANUFACTURERS AND DEALERS

Base Materials

		Carlots	Less Carlots
Barium carbonate ($BaCO_3$), Crude, (Witherite) 90%, 99% through 200 mesh	ton	43.00	46.00
Barium sulphate, in bags	ton	19.00	24.00
Barium sulphate, glassmaker's, carlots, bulk f. o. b. shipping point	ton	15.00-16.00	18.00
Borax ($Na_2B_4O_7 10H_2O$)	lb.	....	....
Granulated	In bags, lb.	.0215	.027-.0295
Powdered	In bags, lb.	.024	.0295-.032
Boric acid (H_3BO_3) granulated	In bags, lb.	.048	.054-.0565
Calcium phosphate ($Ca_3(PO_4)_2$)	lb.	.07	.07½
Cryolite ($Na_3Al\ F_6$) Natural Greenland (Kryolith)	lb.	.0875	.0925
Synthetic (Artificial)	lb.	.0825	.0875
Feldspar—			
20 mesh	ton	11.00-13.25	
40 mesh	ton	11.50-13.75	
Granular	ton	11.75-14.00	
Semi-granular	ton	11.00-13.25	
L. C. L., (Min. 2 tons) $3.00 per ton additional plus charge for bags			
Fluorspar (CaF_2) domestic, ground, 96-98% (max SiO_2, 2½%)			
Bulk, carloads, f. o. b. mines	ton	30.00	....
In bags	ton	31.60	38.00-40.60
Kryolith (see Cryolite)			
Lead Oxide (Pb_3O_4) (red lead) (N. Y.)	lb.	.074	....
In 5 Ton lots	lb.	....	.0775
Less than 5 Tons	lb.	....	.0825
Lime—			
Hydrated ($Ca(OH)_2$) (in paper sacks)	ton	10.50	....
Burnt (CaO) ground, in bulk	ton	7.00	....
Burnt, ground, in paper sacks	ton	9.00	....
Burnt, ground, in 180 lb. drums	Per drum	1.60	1.70
Kiln Dried ($CaCO_3$) 10x30 mesh	ton	1.75	....
Kiln Dried ($CaCO_3$) 16x120 mesh	ton	1.75	....
Potassium carbonate—			
Calcined (K_2CO_3) 96-98%	lb.	.065	.0675
Hydrated 80-85%	lb.	.055	.0575
Salt cake, glassmakers (Na_2SO_4)	ton	15.00	25.00
Soda ash (Na_2CO_3) dense, 58%—			
Bulk	Flat Per 100 lb.	.95	....
In barrels	Per 100 lb.	1.35	....
In bags	Per 100 lb.	1.10	....
Sodium nitrate ($NaNO_3$)—			
Refined (gran.) in bbls	Per 100 lb.	....	2.50-2.90
95% and 97%			
Bulk	Per 100 lb.	1.35	....
200 lb. bags		1.415	1.44
100 lb. bags		1.45	1.475

Special Materials

		Carlots	Less Carlots
Aluminum hydrate ($Al(OH)_3$)	lb.	....	.03½
Aluminum oxide (Al_2O_3)	lb.	.04	.05
Antimony oxide (Sb_2O_3)	lb.	.11½	.12¼
Arsenic trioxide (As_2O_3) (dense white) 99%	lb.	.03	.03½
Barium nitrate ($Ba(NO_3)_2$)	lb.	....	.07¾
Pyrophyllite, (20% Al_2O_3)	ton	9.00	12.00
Sodium fluosilicate (Na_2SiF_6)	lb.	.04¼	.05
Tin Oxide (SnO_2) in bbls	lb.	....	.48
Titanium Oxide (ceramic grade)			
In bags	lb.	.13¼	.13½-.14
In barrels	lb.	.13½	.13¾-.14¼
Zinc Oxide (ZnO)			
American process, Bags	lb.	.06¼	.06½
White Seal, 150 lb. bbls	lb.	.08¾	.09
Green Seal bags	lb.	.08	.08¼
Domestic White Seal bags	lb.	.08½	.08¾
Red Seal, bags	lb.	.07½	.07¾
Zircon			
Refined Granular (Milled .01-.02c higher)		.06½	.07-.08
Commercial, Gran. (Milled .02¼-.02½ higher)		.02¾	.03-.03½

Coloring Materials

		Carlots	Less Carlots
Barium selenite ($BaSeO_3$)	lb.	....	1.40-1.60
(Commercial, 25% Selenium)	lb.	....	.90
Cadmium sulphide (CdS)	lb.	....	.85-.95
Chromite (99% through 200 mesh)	lb.	35.50	40.00
Cerium hydrate—			
100 lb. drums and 600 lb. barrels	lb.	....	.60
Chrome Oxide Green, 400 lb. bbls.	lb.	....	.22-.26
Cobalt oxide (Co_2O_3)			
In bbls. 350 lbs. or more,	lb.	....	1.67
Less than 350 lbs.,	lb.	....	1.77
Copper oxide—			
Red (Cu_2O)	lb.	....	.185
Black (CuO)	lb.	....	.145-.15
Black prepared	lb.	....	.22
Iron Oxide—			
Red (Fe_2O_3)	lb.	....	.0425
Black (Fe_3O_4)	lb.	.04½	.09
Iron Chromate	lb.	....	.035-.05
Lead Chromate ($PbCrO_4$) in bbls.	lb.	....	.145
Manganese, Black Oxide			
In Paper bags	ton	54.50	57.50-62.50
In Burlap bags	ton	57.00	60.00 65.00
In Casks	ton	58.50	61.50-66.50
Neodymium oxalate, 50 lb. drums	lb.	....	3.50
Nickel oxide (Ni_2O_3), black	lb.	....	.35-.40
Nickel monoxide (NiO), green	lb.	....	.35-.40
Potassium bichromate ($K_2Cr_2O_7$)—			
Crystals	lb	.08¾	.09-.09¼
Powdered	lb.	....	.09½-.09¾
Potassium Chromate (K_2CrO_4) 100 lb. kegs	lb.	....	.27
Powder blue	lb.	....	.2075-.2125
Rare earth hydrate—			
100 lb. drums	lb.	....	.35
325 lb. barrels	lb.	....	.30
Selenium (Se) In 100 lb. lots	lb.	....	1.75
In lesser quantities	lb.	....	1.85
Sodium bichromate ($Na_2Cr_2O_7$)	lb.	.06¾	.07-.07¼
Sodium chromate (Na_2CrO_4) Anhydrous	lb.	.08⅛	.08¾-.08⅞
Sodium selenite (Na_2SeO_3)	lb.	....	1.55-1.65
Sodium uranate (Na_2UO_4) Orange	lb.	....	1.50-1.55
Yellow	lb.	....	1.50-1.55
Sulphur (S)—			
Flowers, in bbls	Per 100 lb.	3.35	3.70-4.10
Flowers, in bags	Per 100 lb.	3.00	3.35-3.75
Flour, heavy, in 250 lb. bbls.	Per 100 lb.	2.90	3.25-3.65
Uranium oxide (UO_2) (black, 96% U_3O_8) 100 lb. lots. Black	lb.	....	2.25-2.30
Yellow orange	lb.	....	1.50-1.55

Polishing Materials

		Carlots	Less Carlots
Emery, Turkish	lb.	.063	.07
Pumice Stone,			
American Ground Italian FFF, FF, F	lb.	....	.03
0, 0½, ½, 1.	lb.	....	.03¾
Putty Powder	lb.	....	.38-.42
Rotten Stone, (Domestic)	lb.	....	.03
Rouge, Red	lb.	....	.14
Black	lb.	....	.16

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III. The Composition of Glass
IV. The Chemical Durability of Glass
V. The Viscosity of Glass
VI. The Annealing of Glass
VII. The Surface Tension of Glass
VIII. The Heat Capacity of Glass
IX. The Heat Conductivity of Glass
X. The Density of Glass
XI. The Coefficient of Expansion of Glass
XII. The Elastic Properties of Glass
XIII. The Strength of Glass
XIV. The Thermal Endurance of Glass
XV. The Hardness of Glass
XVI. The Optical Properties of Glass
XVII. The Electrical Conductivity of Glass
XVIII. The Dielectric Constant, Dielectric Loss, and Dielectric Strength of Glass
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The moulds for this bottle were produced on the Gorton Duplicator in half the time formerly required.

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	Duplicator Time	Hand Work	Total		
Bottle Moulds, 9 halves	28 hrs.	87 hrs.	115 hrs.	182 hrs.	67 hrs.
Bottom Plates, 4	4	12	16	27	11
Blanks, 9 halves	14	21	35	122	87
Total Time	46 hrs.	120 hrs.	166 hrs.	331 hrs.	165 hrs.

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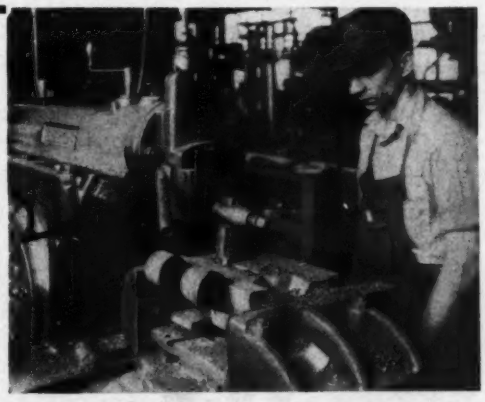

Machining the face of a section for a bottle mould.

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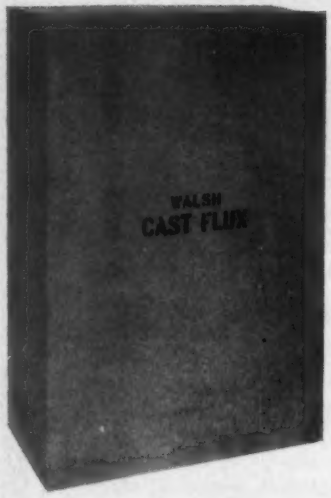

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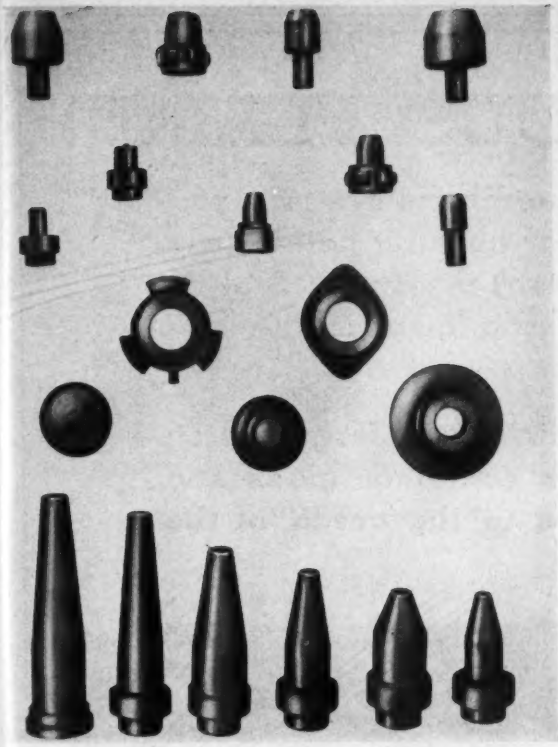
V-2RI

Laclede-Christy



High Thermo-Conductivity with Gunite Guide Rings and Plungers

Because they are specifically designed for use in the glass house, GUNITE guide rings and plungers satisfy the most exacting requirements of glass technologists who expect the operating life of GUNITE to be four or five times that of ordinary glass mould iron.

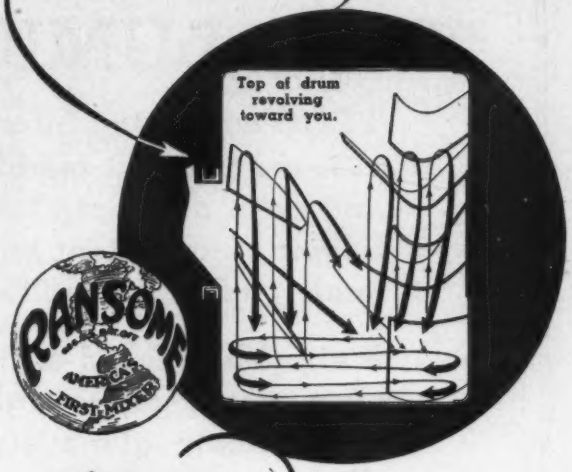
To mention only one of the many advantages of GUNITE—it has excellent thermo-conductivity. One large user of plungers reports that no specific precaution need be taken in the distribution of cooling water in the plunger, as the plungers seem to operate at uniform temperature at all times.

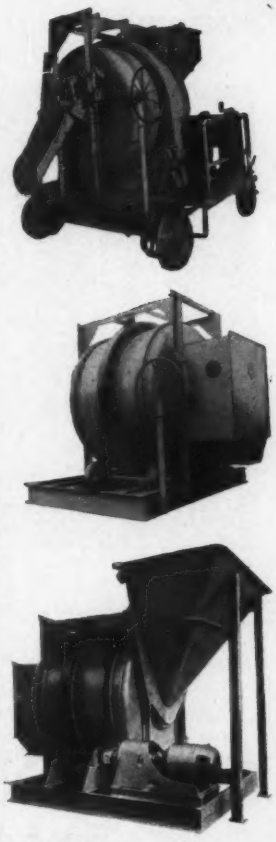
Add to this—just the right hardness and polish to produce ware unusually free from foundry defects—it frees easily from the glass—it does not readily scratch—it's GUNITE.

Miller plungers and guide rings are carried in stock and may be obtained free of pattern charges. A descriptive booklet tells about the complete line of GUNITE glass house castings.

GUNITE
FOUNDRIES CORPORATION
ROCKFORD ILLINOIS
Established 1854

This Mixing Action





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